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MAY 1950
No. 166

ASTM Bulletin

NEWS—News and Provisional Program for 1950 Annual Meeting; District Meetings.

PAPERS—Statistical Analysis; Protective Coatings; Die Casting Flow Calculations; Concrete Bond Measurements.

American Society for Testing Materials

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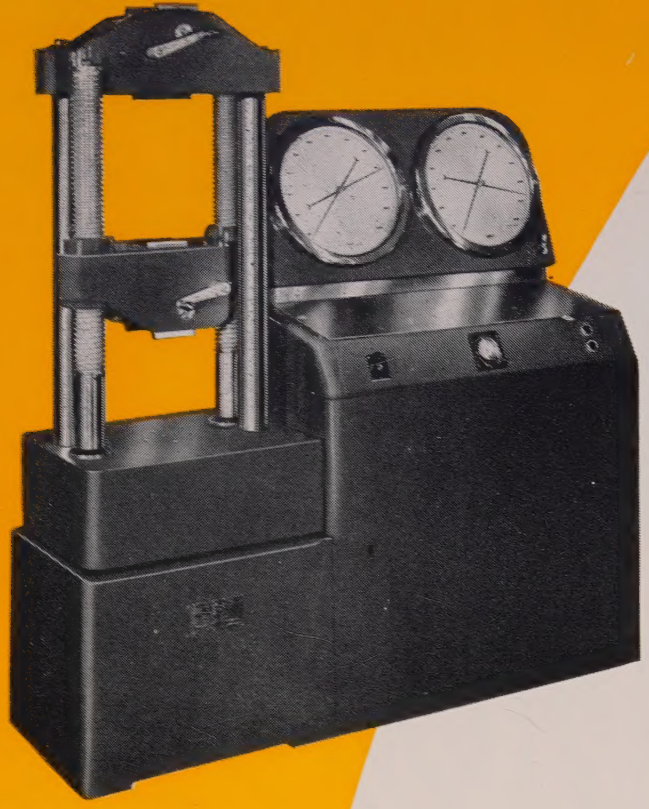
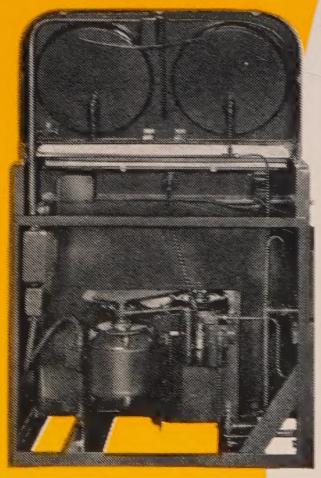


Front view, showing compact, streamlined construction.



Rear view of indicating and pumping unit. Back cover is removable for easy access to oil reservoir, micronic filter, radial piston pump, speed control valve, pump motor and gauges.

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ASTM BULLETIN

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TESTING MATERIALS

This Issue Contains

Annual Meeting News and Provisional Program; Testing Exhibit.....5, 9, 13

The Design and Interpretation of Interlaboratory Test Programs, *by Grant Wernimont*..... 45

Comparative Tests in a Single Laboratory, *by W. J. Youden*..... 48

Discussion of Paper on Electrical Method for Evaluation of Protective Coatings as Moisture Barriers..... 51

Fire-Resistant Finishes for Aircraft, *by J. A. Jones and R. V. Niswander*..... 53

Discussion..... 59

Fatigue Characteristics of Aircraft Materials and Fastenings, *by T. E. Piper, K. F. Finlay, and A. P. Binsacca*..... 60

Discussion..... 64

Flow Calculations for Die Casting Applied to the A.S.T.M. Committee B-6 Test Casting Die, *by Edward Jacobi*..... 65

A New Technique for Bond Measurement in Reinforced Concrete, *by J. Trueman Thompson and Alvin C. Loewer, Jr.*..... 69

NEWS ABOUT THE SOCIETY AND ITS COMMITTEES:

Photographic Exhibit..... 7

New Publications—Book of Standards, Bituminous Materials, Stainless Steel, Knock Manual, A-10 Tables.....25–27

A.S.T.M. Test Methods in Research 28

District Activities..... 30

Technical Committee Notes..... 32

A.S.T.M. Bar Specifications..... 38

Personals; New Members.....41–42

Membership Suggestion Blank.... 42

MISCELLANEOUS NEWS NOTES:

Notes on Laboratory Supplies—Catalogs and Literature; Instrument Notes; News of Instrument Companies.....43–44

Index to Advertisers..... 103

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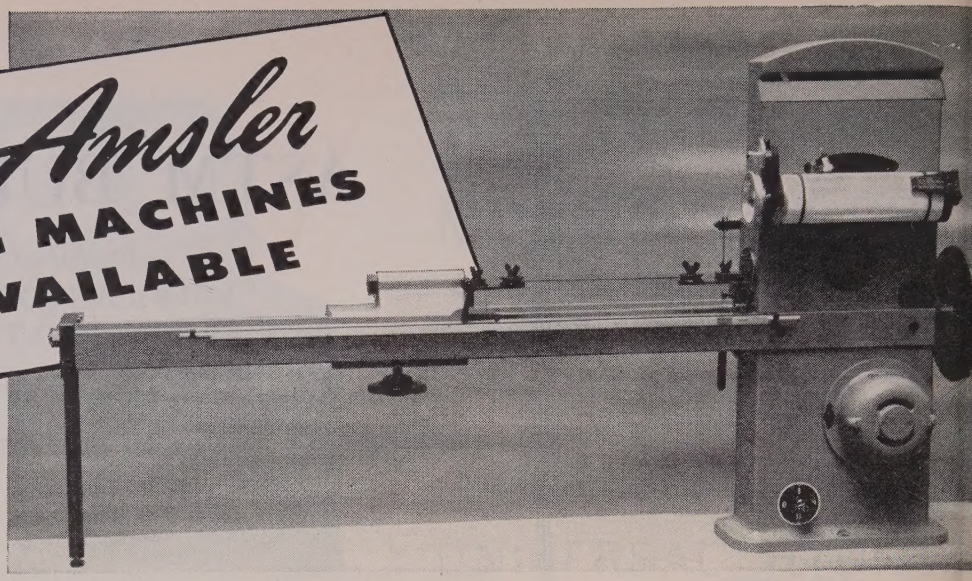
Telephone: Rittenhouse 6-5315 Cable Address: Testing, Philadelphia

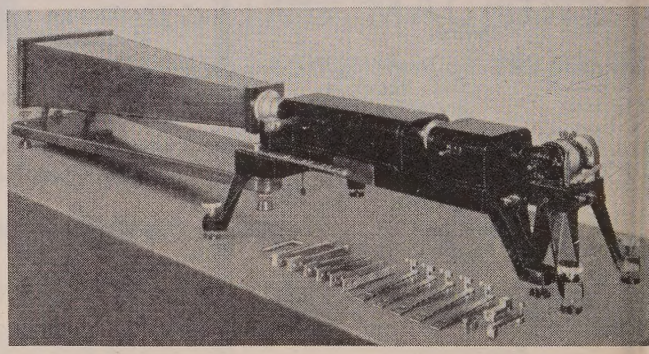
MAY—1950

No. 166

New Amsler
TESTING MACHINES NOW AVAILABLE



BOOTHS 5 & 6 at the A.S.T.M. SHOW



The Amsler Horizontal Tensile Testing Machine has been designed for testing materials of small section or low tensile strength such as fine wires, foils, fibers, fabrics, paper, yarn, leather, rubber, etc. The long horizontal design permits easy access to all parts, unobstructed view of the specimen, convenient gripping mechanisms and sufficient travel for specimens of great elongation such as rubber.

All of the desirable features in a small testing machine are included, such as the highly accurate pendulum load weighing system, five load ranges for greatest sensitivity at all loads, and speed control variable through eight steps from 0.1 to 20 inches per minute.

The tensile load applied is balanced by the deviation of the pendulum from the vertical position. The movement of the pendulum is indicated on a straight line scale located in front of the operator for easy reading. The pointer remains at the maximum load after fracture of the sample. The recording drum is located directly below the load scale. The recorder will plot the elongations as 1/5 size, actual size or double size.

A split nut arrangement on the pulling grip allows quick positioning of this grip to accommodate different length specimens. A wide variety of jaws and clamps are available for holding the different samples.

The Chevenard Micro Tensile Testing Machine has been designed for testing materials of very low strength or of micro dimensions. Samples with a breaking strength as low as one gram (0.035 oz.) may be tested. The machine, however, is extremely versatile having a maximum capacity of 100,000 times the minimum capacity of 100 kg. (220 lbs.). This broad range is obtained by the use of interchangeable dynamometer springs. The pulling speed can be varied between 6 and 300 mm. (0.24 and 12 in.) per minute. This is accomplished by the use of a variable speed motor and a sliding gear change box.

Two interchangeable optical tripods utilizing a light beam and photographic recording provide the utmost sensitivity in the measurement of elongation and the recording of stress-strain curves. Specimens can be tested dry or in a liquid bath and may be from 2 to 150 mm. (0.08 to 6.0 in.) between grips. The grips will accommodate specimens up to 6 mm. (0.24 in.) wide.

A micrometer and accessories are included for carrying out load-elongation cycles between two given values of elongation. The tester is also equipped with an automatic device for carrying out cycles between two given values of the load.

All of these features make the tester ideal for research or control tests on wire or thin metal strip, natural or artificial fibers and textiles, threads, tissues, paper, films of paint or varnish or similar materials.

Prompt delivery on these machines can be made from stock now in U. S. A.

AMSLER LINE OF PHYSICAL TESTING APPARATUS

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Creep Testers	Volume Meters	Vertical & Horizontal Tensile Testers of All Sizes
	Impact Testers	

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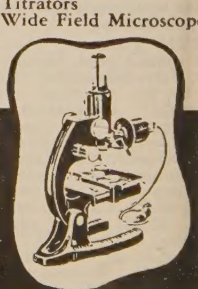


Adolph I. Buehler
OPTICAL INSTRUMENTS
228 NORTH LA SALLE ST., CHICAGO 1, ILLINOIS

ASTM BULLETIN

"Promotion of Knowledge of Materials of Engineering, and Standardization of Specifications and Methods of Testing"

TELEPHONE—Rittenhouse 6-5315

R. E. Hess, Editor
R. J. Painter, Associate Editor

CABLE ADDRESS—TESTING, Philadelphia

Number 166

MAY, 1950

23-Session Technical Program, Numerous Committee Meetings, Apparatus and Photographic Exhibits to Feature 53rd Annual Meeting

Diversified Program and Exhibits Will Attract Members During Week-Long Meeting at Atlantic City, June 26—30, Inclusive

Although the detailed rovisional Program in this Bulletin nd last-minute news on the Apparatus nd Photographic Exhibits will give embers some idea of the features of e Society's 1950 (53rd) Annual Meetg in Atlantic City, June 26–30, the st way of knowing just what an excelnt meeting will be in progress, is to tend. That, of course, is what many ndreds of the Society's members and mmittee members will be doing. It hoped that a great many members ho have not found it possible previously get to an Annual Meeting will do so is year. A very attractive program nd other features are scheduled.

All of the major functions will be at halfonte-Haddon Hall, but some comittee meetings may be scheduled at her nearby hotels. The Philadelphia istrict members are acting as hosts for e meeting, and they plan to have anher interesting dinner and entertainent on Wednesday night, June 28. his is distinctly a social period. Two siness luncheons are scheduled at hich the President's Address will be ven and Honorary Memberships varded, 40- and 50-year Members cognized, and for the first time several Awards of Merit are expected to be given. These luncheons will be on Tuesday and Thursday. Further details will be given all members.

The 1950 Edgar Marburg Lecture which commemorates the name of the Society's first secretary will again be of widespread interest. Dr. Wallace R. Brode, Associate Director, National Bureau of Standards, will cover spectroscopy. The use of various methods of spectrographic analysis is very widespread and new developments are taking place rapidly.

Hotel Reservations

In April each member and committee member should have received from Headquarters a hotel reservation form providing for the sending of room requirements to Chalfonte-Haddon Hall, the headquarters hotel, which is also acting as a clearing house for accommodations. With this circular material was an advance outline of the Annual Meeting sessions and meetings so that members could determine how long they wished to stay at the meeting. This year several of the metals committees will be having committee meetings on Sunday in order that the intensive program, particularly on ferrous metals, can be concentrated in the early part of the week.

Hotel reservations should be made promptly. The number of single rooms is limited and members are urged to share twin-bedded rooms.

Committee Meetings

There will NOT be sent out in advance of the meeting a detailed schedule of the technical committee meetings. Each committee sends to its membership a schedule of its respective meetings.

Usually final details of the times at which many of the technical committees will meet are not completed until early in June. This detailed information is provided in the final program for the meeting given to each member as he registers. However, with the circular letter dated April 24 there was a summary of the days on which the major technical groups are expected to meet, and thus members could plan for their arrival and stay at the Annual Meeting.

Members should look to the schedules they will receive from their respective committee officers for complete information on meetings and a time schedule.

Are you interested in?: Test Programs—p. 45; Statistical Analysis—p. 45, 48; Protective Coatings—p. 51, 53; Fatigue—p. 60; Die Castings Flow Calculations—p. 65; Concrete Bond Measurements—p. 69.

Preprints of Reports and Papers

To each member in good standing there was mailed early in May a Preprint Request Blank which he could mark and return to A.S.T.M. Headquarters, thus making known his desire to have certain papers or reports that would be preprinted. This material probably will be mailed in three installments, the final one just before or during the Annual Meeting. Members attending the meeting can of course obtain, as they register, copies of preprinted papers and reports, or abstracts of items that it was not possible to preprint. *Preprints will be distributed at the A.S.T.M. registration headquarters in Haddon Hall.*

Entertainment Features

Arrangements for the entertainment features of the meeting again are being handled by the Philadelphia District Council, this District serving as the host for the meeting as it did in 1949. The programs arranged last year met with such favor on the part of members and their families that events along similar lines are scheduled, but with different individual features. The dinner on Wednesday night, June 28, will be devoid of any Society business. A predinner cocktail party, and the dinner during which good music is in store, will be followed by an outstanding entertainment program arranged by one of Philadelphia's leading amusement groups. This affair will take place in the Carolina Room at Chalfonte.

The Ladies' Program again will include a tea with a palmist and other features, a game night including bridge and other games, and a special demonstration and lecture by a du Pont specialist on fabrics, clothing, and the like.

Other informal events may be arranged.

Luncheons:

In order to provide suitable occasions for the Annual President's Address and various Society Awards, two luncheons are scheduled. This innovation in 1949 worked out so well that it will be repeated. While these luncheons are a part of the meeting program, many of the ladies attend. No technical work is transacted at the luncheons. Reservation forms and further details will be given in a circular sent to members late in May.

Personnel of Host Committee:

The Philadelphia District Council, which is the administrative group for the District, has constituted itself as a local committee on arrangements. The officers of the Council and the members who are serving as chairmen of committees are as follows:

Chairman: A. O. Schaefer, Midvale Co.
Vice-Chairman: E. J. Albert, Thwing-Albert Instrument Co.
Vice-Chairman: E. K. Spring, Henry Disston & Sons, Inc.
Secretary: Tinius Olsen, 2nd, Tinius Olsen Testing Machine Co.
Dinner: E. J. Albert
Entertainment: L. Drew Betz, W. H. & L. D. Betz
Ladies' Program: Howard S. Phelps, The Philadelphia Electric Co.
Finance: E. K. Spring
Photographic Exhibit: L. Drew Betz
Special Events: H. W. Stuart

The informal Hostess Committee includes the wives of the members of the District Council and of Headquarters Staff members.

Each member and committee member will receive late in May as part of a special circular letter, details of the Ladies' Program. The local committee is anxious to have advance information on the number of ladies who will pa ticipate in the various events, and a r turn-form will provide a means securing this.

Technical Sessions—Papers a Reports

In addition to the 23 formal technic sessions, there will be an informal rou table discussion on heavy forgings in g turbines sponsored by a panel of t Joint Committee on Effect of Temper ture on the Properties of Metals.

There will be over sixty papers pr sented at the sessions—papers relati to the fields of the groups attending t sessions.

Some of the topics to be covered in t sessions are:

- Corrosion and Erosion of Gas Turb Materials (Symposium)
- Methods of Testing, Quality Conta Appearance, Metallography
- Effect of Sigma Phase on the Hi Temperature Properties of Met (Symposium)
- Role of Non-Destructive Testing in Economics of Production (Symposiu
- Chemical Spectroscopy (Marburg L ture)
- Effect of Temperature
- Testing Soils Under Triaxial Load (Symposium)

Provisional Program

A Study of the Provisional Program beginning on page 13 of this Bulletin is the best means for members to get a clear conception of just what sessions are planned and when. Synopses of the papers are provided and there are general statements on some of the symposiums. The final program available at the A.S.T.M. registration desk on the lounge floor of Haddon Hall will contain the final details of the sessions, the Exhibits Directory, and include a complete schedule of all committee meetings, and give data on entertainment. Members will get the final program as they register.

THROUGH PULLMAN CARS TO ATLANTIC CITY

It is again possible to arrange fo through cars to Atlantic City. If there are a sufficient number of A.S.T.M. members from a particular area or route to occupy a Pullman car, arrangement can be made over most lines to hav this car carried straight through t Atlantic City. Those interested should consult their local ticke agency.

Spectroscopy of Non-Ferrous Metals
Fatigue Testing
Steel, Ferro Alloys, Chemical Analysis, Electrical Resistance Alloys
Cement and Concrete, Roofing Materials, Road Materials
Identification and Classification of Soils
Plasters, Adhesives, Shipping Containers
Building Materials, Fire Tests of Materials
Cast and Malleable Iron, Corrosion of Ferrous and Non-ferrous Metals
Industrial Water
Petroleum Products, Fuels, Road Materials, Rubber

All told, there will be presented over ghty technical papers and informal nd formal discussions; a number of ese will be preprinted in advance of ie Meeting. Later, most of the papers nd discussions will be published in the *roceedings*, the ASTM BULLETIN, or in pecial Technical Publications. See ie provisional program printed in this ULLETIN for times and places of the arious symposium papers and report ssions.

as Turbine Materials:

Under the auspices of the Joint Committee on Effect of Temperature, this mposium on Monday afternoon is ade up of seven papers. The corro-on at high temperatures of metals due coal or oil ash will be described as ill the stress-rupture properties of aterials exposed to leaded gasoline oducts and nickel alloys exposed to lfur dioxide atmospheres. Also, the fect of environment, in general, on ress-rupture properties at elevated mperatures will be surveyed.

One paper describes the surprising agnitude of the hydrogenizing effect of eam and shows moisture in a heat eating atmosphere to be an important urce of embrittling quantities of hy-ogen. In another paper, studies have en made on the dependence of creep te on the surface condition of nickel. will be interesting to see if there is a rrelation as was observed in both the lycrystalline and monocrystalline rms of zinc. A related Discussion nel on Heavy Forgings in Gas Turnes will also be held, Tuesday morn-g.

fect of Sigma Phase:

Also under the auspices of the Joint mmittee is the symposium on the fect of Sigma Phase on the High-mperature Properties of Metals. here is much interest in the structure, currence, and effects of the sigma ase in austenitic steels. The various thors will show the effect of prolonged gh-temperature exposure on the struc-re and identification of various stainless steel types—especially those containing columbium and molybdenum. The mechanism of precipitation and resolution of sigma phase will be described. X-ray studies of the phase in various alloy systems will be presented. The effect of the sigma phase in various alloy systems on mechanical properties will also be discussed, including some of the cast forms of the alloys. On the behavior of stabilized 18–8 Cr-Ni steels in concentrated nitric acid, a paper will be given that describes the influence of sigma phase.

Triaxial Load Testing of Soils:

With 10 papers constituting the symposium, this relatively new topic of significance will be greatly expanded. The effort is under the auspices of Committee D-18 on Soils. The interpretation of triaxial compression test data as well as their applications will be discussed by the various authors. In one paper, an apparatus for conducting the test on large soil specimens is described. The application to highway materials, including asphaltic and subgrade mixtures will be covered in other papers, as well as the adaptation to flexible bases and foundations. Emphasizing design of asphalt highways, flexible pavement performance studies have been made and the results will be presented. New developments for partially saturated soils will also be outlined. The shear characteristics of remolded earth materials will be described.

Identification and Classification of Soils:

Four—possibly six—papers will constitute a symposium on soil classification. Since the soil engineer must reliably know with what soil he is dealing and with what controlling conditions he is faced when he builds some structure on that soil, he must have available for his use an identification and classification system that is accurate and which has been developed with cognizance of the inherently complex nature and behavior of soils. Realizing this, Committee D-18 on Soils has been preparing this symposium carefully, to attempt a presentation of the ideas, and data, of the best minds concerned with this problem. Emphasis will be placed on the use of soil identification and classification as applied to highway construction.

Nondestructive Testing:

It is obvious that the economic significance of nondestructive testing is greater than ever before. Because of this, more and more thought and action is being devoted to the selection, development, and use of nondestructive test methods.

In addition to a presentation of the general nondestructive test methods from a viewpoint of their principles and mechanics, inspection methods of castings, wrought products, and weldments are covered. Also the defects and discontinuities that can be revealed in these products by present nondestructive methods are outlined.

Chemical Spectroscopy:

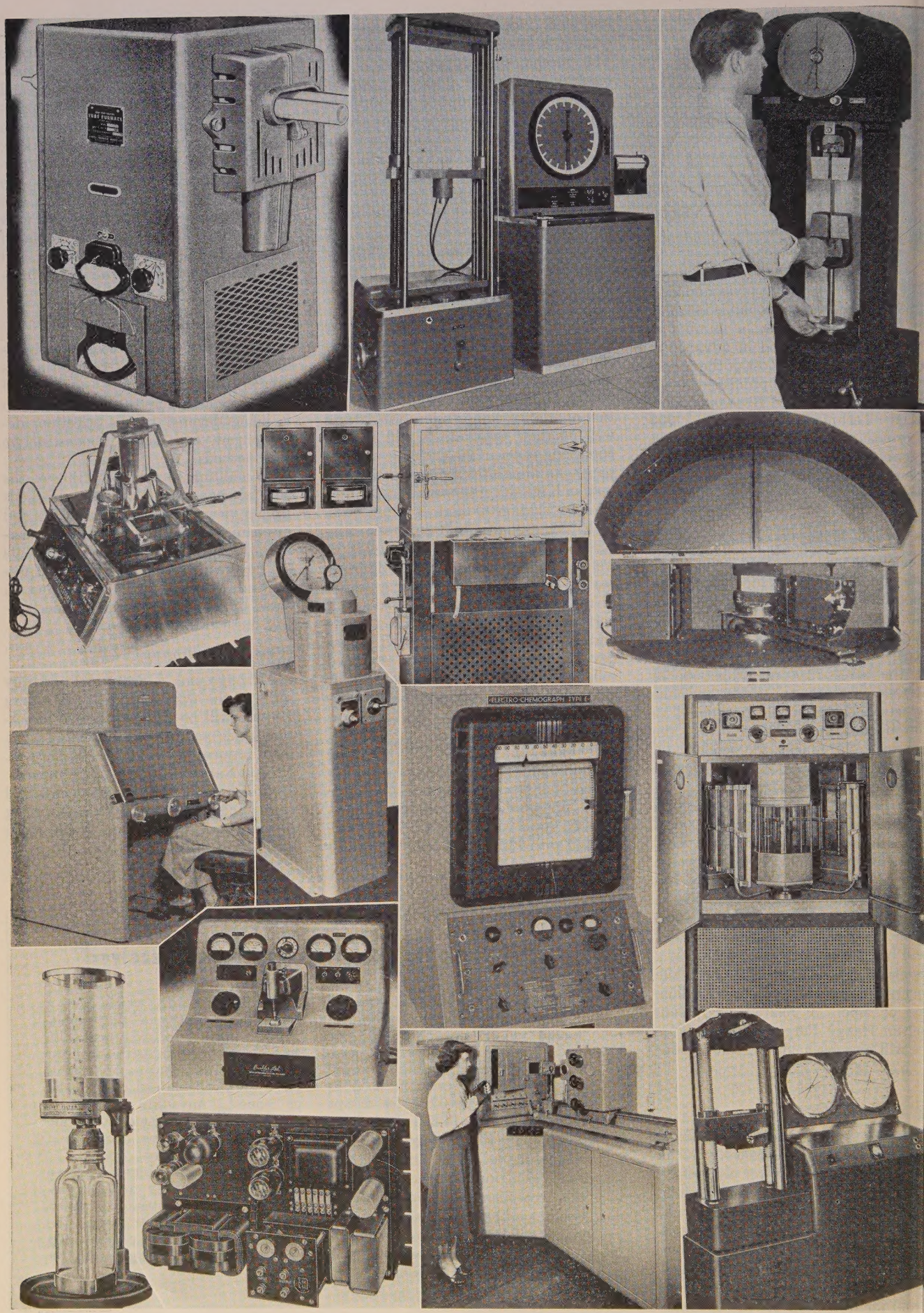
Although not a symposium in any sense of the word, this year's Marburg Lecture will be devoted to this important topic and will be presented by a man eminent in his field—Wallace R. Brode, National Bureau of Standards. He will speak on the relation of chemical spectroscopy to the analyses and testing of materials, as described in the April ASTM BULLETIN.

Photographic Exhibit Entries Being Received

ENTRIES for the 1950 Photographic Exhibit, with its Sections on Radiography and Photomicrography, are being received. All those who have in mind submitting prints are urged to get their entries in as soon as possible. The last date for receipt of entries is June 14 and the judging date set by the Photographic Committee, headed by L. Drew Betz, is June 16. However, the judging of the photomicrographs, including the electron micrographs, and the radiographs will be handled by the respective technical Committees E-4 and E-7, probably at Atlantic City.

An exhibit blank, which gave a complete description of the exhibit, with an entry form, was mailed to each member and committee member in April. Additional copies of this blank are available and will be sent on request. Anyone is eligible provided he is either a member, serving on technical committees, or employed by a member company.

The committee urges all those interested to get their material prepared and their entries completed soon. As in previous years, the photographic theme is concentrated on "Materials, Testing, and Research."


ELECTRO CHROMOGRAPH TYPE E

New Instruments Will Feature 1950 Testing Apparatus Exhibit

New Equipment and Laboratory Supplies Will Be Shown by Leading Apparatus Manufacturers and Distributors; in Progress throughout the Annual Meeting June 26–30, Atlantic City, N. J.

ANYONE concerned with research, testing of materials, and in laboratory and production control operations will find much of interest in the 1950 A.S.T.M. Exhibit of Testing Apparatus and Related Equipment at Chalfonte-Haddon Hall throughout the week beginning June 26. Many of the country's leading manufacturers of apparatus and instruments are participating. There has been a complete sellout of available space. Many special booth displays are being arranged and each exhibitor will have material that will be of interest to wide segments of the men who will visit the exhibit.

Anyone concerned with the material in the Exhibit is cordially invited to attend. Registration at the Annual Meeting is not necessary, but an Exhibit attendance record is maintained.

Brief descriptions of the equipment expected to be shown are given in the following pages. While much of the equipment is used in carrying out A.S.T.M. tests, obviously much of it is not covered in the Society's procedures, but does find important use in industry.

The apparatus displays will be in the Vernon Room and Garden Room adjacent to the A.S.T.M. Registration Desk, and the Photographic Exhibit will be part of these exhibition rooms. The tentative exhibit hours are as follows, but consult the final program available at the meeting for last-minute schedule:

June 26, Monday—12 noon (opening) to 9 p.m.
June 27, Tuesday—9:30 a.m. to 6 p.m.
June 28, Wednesday—9:30 a.m. to 6 p.m.
June 29, Thursday—9:30 a.m. to 6 p.m.
June 30, Friday—9:30 a.m. to 1 p.m.

The following descriptions are based on information requested from exhibitors:

American Instrument Co.
Booth 36

Included in this display of materials testing equipment, there will be featured two of the company's most recent developments: (1) Humidity-temperature test apparatus which affords various types of control to meet almost every conceivable type of humidity-temperature test requirement, including program schedules of interest to government laboratories and manufacturers supplying equipment to the government. (2) Motor-driven flow table which conforms to the latest A.S.T.M. specifications for determining the flow of cement.

H. Reeve Angel & Co., Inc.
Booth 34

This company will exhibit Whatman and Reeve Angel Filter Papers. Especially featured will be ash-free Filter Papers for gravimetric analyses particularly of ferrous and non-ferrous metals and their ores. The use of Filter Papers in partition chromatography, interest in which has been enthusiastically revived recently, will also be stressed.

Atlas Electric Devices Co.
Booths 19, 20

On display will be the new Model XW Weather-Ometer which embodies all of the desirable features requested by the various technical committees. This new unit, a completely redesigned and modernized version of the X-1-A, employs many new features used for the first time in an accelerated weathering machine as well as those that have made the Twin Arc Weather-Ometer so well known for its automatic control of test conditions.

Baird Associates, Inc.
Booths 40, 40A

This company will have its 3-Meter Grating Spectrograph in operation. The instrument is the latest model of a distinguished series. Earlier models, used over the past 13 years, have served to develop new techniques and to bring spectrographic analysis from infancy to its present state of wide use and high recognition. The Baird Associates 3-Meter Grating Spectrograph has become one of the most essential instruments in research and control laboratories. Successful applications are found in work with rocks, minerals, ores, concentrates, and other metallic and nonmetallic substances studied or held to strict control of composition. Many problems in the fields of determinative mineralogy, geological research, age of earth studies, prospecting, concentrating, smelting, refining, and casting require analyses obtainable only by means of spectrochemical techniques.

The Baldwin Locomotive Works
Booths 1, 2, 3

This exhibit will include a 5000-lb. capacity P-T-E Machine showing its accuracy and ease of operation in testing plastic specimens. A microformer recorder will record the test to fracture. A Model 60-H Mechanical Testing Machine and a 60,000-lb. capacity Universal Baldwin Tate Emery machine will be the larger pieces of equipment in the booth. A complete exhibit of SR-4 Strain Gages together with the new Type "L" Indicator, the BA-1 Amplifier, and various strain following equipment will also be shown.

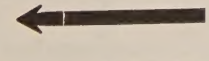
Bethlehem Apparatus Co.
Booth 52

Thorough cleaning of mercury, annoying and expensive chore, is reduced to extreme simplicity by the Bethlehem Apparatus Co.'s Oxifier and Type "F" Filter. The motor-driven Oxifier purifies mercury of dissolved base metals by oxidizing them to dry, readily separated powder. The Type "F" Filter, employing the gold adhesion principle, removes floating dust, oil, grease, water, oxide-scum, and other foreign matter. Either apparatus may be used independently, but together they comprise a cleaning method of great convenience and thoroughness.

Brabender Corporation
Booth 48

The Brabender display will include a number of pieces of equipment, among them being the Plastograph (plastometer), Thermostat (water bath), Viscograph (viscosimeter), Semi-Automatic Moisture Tester and Recording Viscosimeter.

Some of the Equipment to Be Displayed in the 1950 A.S.T.M. Exhibit of Testing Apparatus and Related Equipment, Chalfonte-Haddon Hall, Atlantic City, N. J., June 26–30, incl.



Top Row, l. to r.: A New Electronic Carbon-Sulfur Furnace for Steel Analysis; A 5000-lb. Pneumatic Testing Machine; A Low-Cost Testing Machine with Dual Capacities. Upper Middle Row, l. to r.: A Brittle Point Tester for Rubber and Such Elastomers; A New Humidity Tester; Interior of New Colorimetric Goniophotometer. Lower Middle, l. to r.: A Telereader for Rapid Reading of Data from Oscillograph Charts; New Ductility Testing Machine; Latest Model Electrochemograph; New Model Weather-Ometer. Lower Row, l. to r.: Mercury Filter; Compact Device for Controlled Voltage; Above This: Automatic Electrolytic Polisher; Latest 3-Meter Grading Spectrograph; Latest Type Hydraulic Universal Testing Machine.

Brookfield Engineering Labs., Inc.
Booth 51

The display of Brookfield will include the Brookfield Synchro-lectric Viscometer, Viscotrol (automatic controlling viscosity controller), ViscomaT (automatic recording and controlling unit), and Counter-Rotating Laboratory Mixer.

The Brush Development Co.
Booth 47

This booth will have the BL314 Uniformity Analyzer—a new electronic instrument designed to measure and make a permanent record of the irregularities in weight per unit length of yarn, roving, and sliver; the BL320 Universal Amplifier—when used with the BL201 Brush Magnetic Direct Inking Oscillograph, provides a complete package unit for the measurement of strain or other phenomenon where a resistance sensitive pickup is employed. Also on display will be the BL933 Chart Takeup Drive which provides a convenient means of reeling recorded chart paper from a BL201 or BL202 oscillograph into a form which is readily stored, and the BL103 Surface Analyzer for measuring average root mean square surface irregularities and recording a profile of the surface under investigation. The BL928 Dual Channel D-C. Amplifier and BL221 Single Channel Oscillograph will also be in the exhibit.

Buehler Ltd.
Booths 5, 6

Buehler Ltd. will have in operation various items from its complete line of sample preparation equipment for the metallographer. This line includes cut-off machines, grinders, mounting presses, and mechanical and electrolytic polishers. Amsler testing equipment, Chevenard micro testing equipment, the Ames portable Rockwell tester, and optical equipment for the metallurgical laboratory will also be demonstrated. The improved Buehler-Waisman Electro-Polisher will prepare samples for microscope inspection in less than a minute while you watch.

Burrell Corporation
Booths 22,23

This company, long leaders in the manufacturing of carbon and sulfur determination equipment for the steel industry, announces a new electronic carbon and sulfur furnace. Along with the display of the furnace, there will be in operation in their booth a carbon and sulfur train for actual on-the-spot analyses of Bureau of Standard samples.

The Central Scientific Co.
Booth 18

This exhibit features the Cenco-duNouy Tensiometer for measuring interfacial and surface tensions of transformer, lubricating, Diesel engine, and other oils for sludge condition or breakdown point (see D 971 – 48 T); the line-operated Cenco Titration-pH Unit suggested for neutralization value of petroleum products (see D 117 – 47 T and D 664 – 49), saponification numbers (see D 939 – 47 T), pH values (E 70 – 46 T), dissolved oxygen in industrial waters (D 888 – 49 T), etc.; the Cenco Entrained Air Indicator for measuring entrained air in fresh concrete mixes (complies with Method C 231), and other new instruments for laboratory testing.

Consolidated Engineering Corporation
Booths 37, 38

This exhibit will include the Telereader, an instrument for the rapid reading of data points from oscillographic (or similar) charts up to 12 in. wide—and when used with a companion instrument, the Telecorder, for the recording of up to 50 data points per min. on IBM cards. Such rapid reading and recording of chart data is extremely useful in evaluation of multitrace oscillograph records containing many categories of information recorded simultaneously. In a matter of hours an oscillograph, for example, is capable of recording data which may require hundreds of man-hours for evaluation by older methods. With the Telereader-Telecorder combination, chart evaluation often can be accomplished in minutes. Operator fatigue is virtually eliminated and accuracy far exceeds that of manual reading.

Corning Glass Works
Booth 25

This display will feature Pyrex brand Red Line Graduated cylinders with the "glass bumper." Also to be shown will be new burettes of precision bore tubing and a new type of tubular fritted glass filter. Other items of interest will be Vycor brand 96 per cent silica glass, new sizes in high vacuum stop cocks and ball and socket interchangeable ground joints.

Custom Scientific Instruments, Inc.
Booth 39

CSI offers for inspection its feature high precision instruments: The Stoll-Quartermaster Universal Wear Tester is designed for quantitatively measuring resistance of fabrics and fabric-like materials to Flat abrasion, Flex abrasion, and Edge abrasion; the Templin Calibrator, checks extensometers, strain gages, and test indicators accurately; the High-Speed Angle Centrifuge, provides flexibility and ease of sterilization.

J. W. Dice Co.
Booth 27

This company is showing a widely diversified "family" of new and unusual instruments for both nondestructive and physical testing and measuring of metals and other materials. Out-of-the-ordinary instruments, employing ultrasonic, magnetic, hydraulic, and other principles, will be shown in actual operation on typical of the more difficult materials testing and measuring problems encountered in shop and laboratory.

Eastman Kodak Co.
Booths 45, 46

Photographic materials and optical equipment for industrial and scientific testing will be included in the Eastman Kodak exhibit. Among the equipment which will be shown is a new optical comparator, the Kodak Contour Projector, Model II. Other sections of the exhibit will deal with photographic recording materials, high-speed motion pictures, and materials for metallography and X-ray inspection.

Henry A. Gardner Laboratory, Inc.
Booth 43

New pieces of equipment to measure gloss will be featured in this booth display. Among these will be a colorimetric goniophotometer; a 22-deg. glossmeter for high-gloss materials; and an 85-deg. sheenmeter for low-gloss interior paint finishes. The well-known Hunter Color and Color-Difference Meter will also be shown. In addition to this optical equipment, the Laboratory will show some of its apparatus for physical testing.

General Radio Co.
Booth 11

This company's exhibit will include equipment for dielectric measurements covering a frequency range from 20 cycles per second to 1000 megacycles per second, various special-purpose impedance bridges for insulation testing, production measurements, and laboratory use, instruments for the measurement and analysis of vibration, a Strobolume for very slow speed stroboscopic work and for single-flash photography, and a new dynamic Polariscope, which makes possible for the first time the photography of stress patterns in plastic models under dynamic conditions. This instrument opens up a completely new field of stress analysis and while only lately available commercially, has already been used in research laboratories with complete success.

Hanovia Chemical & Manufacturing Co.
Booth 49

The highlight of this exhibit is a newly developed equipment for accelerated aging and fading of materials. Whereas a mercury arc lamp is the main source of energy the equipment is so designed that other lamps which will compliment the radiations of the mercury arc may be included. Moreover moisture control can be furnished as an accessory, thus providing a dew cycle. Mechanics of the apparatus are such that uniform exposure of all samples will be accomplished. Comprehensive equipment for Black Light examinations will be shown. Several new models will be exhibited for the first time, and various fused quartz apparatus made in accordance with the A.S.T.M. standards

Some of the Equipment to Be Displayed in the 1950 A.S.T.M. Exhibit of Testing Apparatus and Related Equipment, Chalfonte-Haddon Hall, Atlantic City, N. J., June 26–30, 1950, incl.

Top Row, l. to r.: Latest Type Electronic Recorder; New Lamp for Special Light Examination; Container Testing Machine. Upper Middle, l. to r.: A New Spectrograph; Latest Type Hardness Tester; Micrometer for Low Resistance Measurements. Lower Middle: Portable Non-Destructive Tester; Automatic H_2S Analyzer; Compact Relative Humidity Thermometer; A New Dynamic Polariscope. Lower, l. to r.: Casting Ready for Radiographic Examination; lower left-hand corner, Gage for Measuring Thickness of Metals from one Side; New Contour Projector; Compact Universal Testing Machine.

will be shown together with special fused quartz of grade optical clarity.

Instron Engineering Corp.
Booths 13, 14

The Instron Tensile Tester embodying a low enertia strain gage recording system and electronic speed controls, with a wide range of load scales featured from 2 g. to 5000 lb. full scale, will be on display in this booth. A number of accessories will be shown such as an instrument for automatic evaluation of energy absorption, a complete set of newly designed grips, and compressional load recording equipment.

Jarrell-Ash Co. and National Spectrographic Laboratories, Inc.
Booths 28, 29, 30

This exhibit will display for the first time the new Hilger Raman Spectrograph and Source Unit, and the newly improved HRX X-ray Unit with cameras. There will be both an inexpensive spectrochemical installation built around a Jaco Replica Grating Spectrograph and Hilger Microphotometer, and a more elaborate outfit featuring a Hilger Prism Spectrograph, NSL Triple Source, and Jaco Microphotometer. Other Hilger instruments will include the Steeloscope, for rapid sorting of steels, Spectrometers, Monochromators, Refractometers, and Polarimeters.

Leeds & Northrup Co.
Booths 7, 8

Several new types of testing equipment will be featured by this company in their exhibit. Among these will be the Speedomax "X-Y" Recorder, which automatically charts the relationship between two independent variables, one on its X-axis and the other on its Y-axis. The latest model Electro-Chemograph will also be shown and an advance showing will be made of the new line of L&N D-C Amplifiers, and of the new type of adjustable capacitance standard embodying new construction of low-loss capacitance elements. Completing the exhibit will be the latest model L&N A-C Decade Resistance Box, with high-stability, low-resistance switches; the Type E Galvanometer, a high-sensitivity, short-period detector with integral lamp and scale; and a Speedomax Recorder used with the D-C Amplifier for measurement of insulation leakage current.

Lindberg Engineering Co.
Booth 18

This company will show the Lindberg "H-F" Combustion Unit which is revolutionizing carbon and sulfur determinations in various laboratories throughout the country. Ready for instant use–instant temperatures above 3000 F.—for steel, cast iron, alloys, or stainless samples—volumetric or gravimetric.

Magnaflux Corp.
Booth 53

On display will be three methods of Nondestructive Testing. These are expected to correlate closely with the theme of the Committee E-7 Symposium: "The Role of Nondestructive Testing in the Economics of Production."

Magnaflux, Zyglo, and the Magnaflux Sonizon will be in operation. A portable type KDN Magnaflux-Magnaglo unit will be shown as it operates in a number of production plants to control processes which can cause defects in manufactured parts.

Zyglo will be shown as used on nonmagnetic materials to find cracks, shrinkage, and similar defects. The Magnaflux Sonizon will be in operation. This ultrasonic instrument tests for thickness by resonance methods with contact to one side only, and also locates laminar type defects.

National Forge & Ordnance Co.
Booths 41, 42

This company will exhibit its new, compact Table Universal Testing Machine. Available in either 30,000-lb. or 15,000-lb. maximum capacities, each having three loading ranges. Container compression testers of 5000-lb. and 750-lb. capacity will also be on exhibit. A new development in testing machine calibration equipment, the National Forge Verification Column, will be shown, along with accessories for testing of containers and boxboard.

Tinius Olsen Testing Machine Co.
Booth 35

On exhibit in the Olsen booth will be the new Olsen Electronic Recorder Model 49 and its accompanying Extensometer and Compressometer Instruments which are used in tension and compression as well as flexure work. Magnifications of strain in tension testing as well as compression testing, can be changed during the test by switching the multi-selector switch in the center of the recorder bracket. An LC (Low Cost) Testing Machine with dual capacities of 10,000 and 1000 lb. will be in this display. Also exhibited will be the Olsen-Muhlenbruch Troptometer for use in conjunction with torsion testing machines for producing torsion curves. An M.I.T. Paper Tester which is a standard folding endurance tester, and a Torsion Stiffness Tester designed primarily for plastics and which is one of the line of plastic testers manufactured by Olsen will complete the equipment in the exhibit.

Radium Chemical Co., Inc.
Booth 15

In this booth will be shown radiographs taken with radium, radium containers, and shipping and storage boxes. Representatives in attendance will discuss with visitors technique for taking radiographs with radium as the source of energy, and will also explain the manufacture of the radium containers, as well as protective measures for handling radium.

Riehle Testing Machines Division American Machine and Metals, Inc.
Booths 32, 33

One of the machines to be exhibited in this booth will be Riehle's new Model MA Universal Hydraulic Testing Machine. The Model MA is a low-priced machine suitable for all three standard tests (tension, compression, and transverse). Special tools can be furnished for Brinell hardness, timber testing, and other special tests. The MA is built in three capacities, 60,000 lb., 120,000 lb., and 300,000 lb. The 60,000-lb. model will also be on display. Riehle's Portable Hardness Tester for specimens up to 5 in. in diameter or thickness will also be included in the exhibit.

Rubicon Co.
Booth 54

In addition to well-known Rubicon instruments for precise laboratory measurements, this company will have in operation an instrument believed to be the first commercial automatic recording chemical analyzer based on the measurement of light reflected from a chemically sensitized surface. Developed originally for the determination of H_2S in ammonia synthesis gases, this analyzer is currently used also in fuel gas purification and atmospheric pollution work. Wide range and high specificity are features of this instrument. Concentrations of as little as 0.000001 per cent of H_2S can be detected.

Scott Testers, Inc.
Booth 2

In this display will be the ORR-L5 tensile tester, displayed for the first time. It is used for testing high elongation materials. Also exhibited will be the final design of the Scott Brittle Point Tester which performs the brittle point test in conformity with A.S.T.M. Method D 746 upon vulcanized rubber and other elastomers. In addition to these two machines, the Scott Testers booth will also contain a complete pictorial coverage of their Mooney Shearing Disc Viscometer and standard tester for scorch characteristics with latest recorders.

Sperry Products, Inc.
Booths 9, 1

This company's display will feature ultrasonic nondestructive testing instruments—Reflectoscope and Reflectogage. Continuous demonstrations will show how the Reflectoscope is used for locating defects in metals, and the Reflectogage for measuring thickness of metals from one side only.

Associated with the ultrasonic equipment in the exhibit will be Sperry hydraulic remote controls, self-sealing couplings and custom-built transformers.

Steel City Testing Machines, Inc.
Booth 2

This display will feature the Ductility Testing Machine which is used for testing the drawing qualities of sheet metal. Other machines to be exhibited by the company will be a dead-weight Brinell Testing Machine, a Portable Brinell Tester, and a direct-reading type Proving Ring. Background of the exhibit will incorporate photographs of other types of Steel City equipment including special machines of various kinds.

The Superior Electric Co.
Booth

This display will include the Varicell—a compact source of low variable d-c voltage, which operates from a 95–13 volt, 60 cycle, single phase source and delivers a variable d-c. output voltage 0–30 volts d-c. at 15 amperes. The Stabline automatic voltage regulator type IE5101R, which is completely electronic and instantaneous in operation will also be exhibited, together with Voltbox a-c power supply type UC1M—a compact portable source of variable a-c. voltage. Powerstat variable transformer types 1 and 216, redesigned units incorporating all features required for a-c. voltage testing will also be exhibited.

(*Continued on p. 40*)

This Program is Subject to Change

All time indicated in Eastern Daylight Saving Time

Provisional Program

FIFTY-THIRD ANNUAL MEETING

of the

AMERICAN SOCIETY FOR TESTING MATERIALS

ATLANTIC CITY, N. J.

JUNE 26–30, 1950

Committee Meetings held throughout the week at Chalfonte-Haddon Hall

MONDAY, June 26	TUESDAY, June 27	WEDNESDAY, June 28	THURSDAY, June 29	FRIDAY, June 30
Morning				
Committee Meetings only	Round Table Discussion of Jt. Comm. on Effect Temp.—Gas Turbine Panel (Heavy Forgings) *4th* Symposium on the Role of Nondestructive Testing in the Economics of Production (Reports A-7, E-7) *5th* Luncheon Session—President's Address, Report of Board of Directors, Award of Honorary Memberships	*9th* Session on Effect of Temperature *10th* Symposium of Methods of Testing Soils Under Triaxial Loading	*13th* Session on Nonferrous Metals, Spectroscopy (Reports B-1, B-2, B-6, B-7, B-8, E-2) *14th* Session on Steel, Ferro Alloys, Chemical Analysis (Reports A-1, A-9, E-3) *15th* Session on Cement and Concrete, Roofing Materials (Reports C-1, C-2, C-4, C-9, C-13, D-8) *16th* Luncheon Session—Award of Merit, Recognition of 40- and 50-Year Members	*20th* Session on Plastics, Adhesives, Shipping Containers (Reports D-6, D-10, D-14, D-17, D-20)
Afternoon				
1st Symposium on Corrosion and Erosion of Gas Turbine Materials	*6th* Symposium on Effect of Sigma Sigma Phase on the High Temperature Properties of Metals (*Continued*) (Reports E-4, Jt. Effect Temperature) *7th* Symposium on the Role of Nondestructive Testing in the Economics of Production (*Continued*)	*11th* Symposium on Methods of Testing Soils Under Triaxial Loading (*Continued*) *12th* Session on Fatigue Testing (Reports B-4, E-9)	*17th* Report Session—(Reports C-14, C-15, C-18, C-19, C-21, C-22, D-7, E-6) *18th* Report Session—(Reports D-1, D-5, D-9, D-12, D-13, D-16)	*21st* Session on Building Materials, Fire Tests of Materials (Reports C-7, C-8, C-11, C-16, C-17, E-5) *22nd* Session on Corrosion of Ferrous and Non-ferrous Metals, Cast Iron, Water (Reports A-3, A-5, A-10, B-3, B-5, D-19, Jt. Boiler Feedwater) *23rd* Session on Petroleum Products, Fuels, Road Materials, Rubber (Reports D-2, D-3, D-4, D-11, D-15)
Evening				
2nd Session on Methods of Testing, Quality Control, Appearance, Metallography (Reports E-1, E-11, E-12) *3rd* Symposium on Effect of Sigma Phase on the High Temperature Properties of Metals	*8th* Marburg Lecture—Chemical Spectroscopy, by Wallace R. Brode Medal Awards	Cocktail Party and Annual Dinner Entertainment	*19th* Symposium on Identification and Classification of Soils (Report D-18)	

Monday, June 26 2 p.m. First Session

Opening Session

Symposium on Corrosion and Erosion of Gas Turbine Materials

Formal Opening of the Fifty-third Annual Meeting. President J. G. MORROW.

Symposium on Corrosion and Erosion of Gas Turbine Materials

The gas turbine builder may be called upon to supply turbines for atmospheres all the way from those produced by burning high octane gasoline to those from the use of Bunker C. residual fuel oil or coal. This symposium presents some papers on the fundamentals of gas—metal reactions at high temperatures, along with studies of the effects of specific atmospheres on the various heat-resisting alloys used in gas turbine construction. Also included are papers on the effects of oil ash and coal ash in contact with these metals at elevated temperatures. Protective coatings are also discussed.

The Symposium was sponsored and developed by the Gas Turbine Panel of the Joint Committee on Effect of Temperature on the Properties of Metals.

Coal Ash Corrosion of Metals at Elevated Temperatures. C. T. Evans, Jr., The Elliott Co.

A cooperative study with the Locomotive Development Committee of the Bituminous Coal Research Association and the Crucible Steel Company of America was conducted with S-588 alloy at 1350 F. Stress rupture tests of specimens in contact with raw coal ash from representative Illinois coal and specimens coated with separated Illinois coal ash were compared with "blank" specimens.

Several other metals of interest to the builders of gas turbines for locomotive service were tested in unstressed condition at 1000, 1350, and 1500 F. in contact with representative Ohio coal ash.

The tests demonstrate that these coal ashes or coatings from coal ash are inert to these alloys at these temperatures.

Stress Corrosion Tests on Turbo-Supercharger Materials in the Products of Combustion of Leaded Gasoline. G. B. Wilkes, Jr., General Electric Co.

Stress-corrosion tests were made on 18 alloys. The corroding agents were the products of combustion of leaded aircraft gasoline. Tests were made under both constant temperature and cyclic temperature conditions. Under the conditions of these tests, the combustion products are somewhat corrosive if the temperature is cycled but not at constant temperature. The acceleration of strain due to temperature cycling alone has a greater detrimental effect on strength. From the results of these tests, certain speculations are possible concerning the process by which products of combustion of leaded gasoline cause corrosion.

The Surface as a Limiting Factor in Creep. R. Pickus and Earl R. Parker, University of California.

In the course of ONR sponsored research investigation of certain aspects of creep an interesting dependence of the creep rate of zinc on the condition of the specimen surface was observed.

The investigation was extended to a study of nickel to determine whether the behavior observed is of a general nature and applies as well to high-temperature metals.

This paper reports the results of experiments comparing the temperature dependence of creep of "A" nickel in two environments—purified hydrogen and nitrogen. The nitrogen contains a small percentage of oxygen, and thus produces a thin oxide coating. Preliminary experiments at a single temperature have already shown differing creep rates, dependent upon the environment.

The Effect of Environment on the Stress-Rupture Properties of Metals at Elevated Temperatures. O. Cutler Shepard and Willis Schalliol, Stanford University.

Stress-rupture tests in controlled atmospheres are reported for low-carbon steels and for Hastelloy "C." Differences in the amount of intergranular cracking and in the time to rupture were observed with differences in the composition of the environment. Hastelloy "C" exhibited greatest rupture strength in air. For this reason it is considered dangerous to use tests in air to predict the service life of metals in environments other than air.

Preliminary Studies of the Effect of Oxidizing Sulfurous Atmospheres on the Rupture Strengths of Inconel "X" and Inconel. A. M. Talbot and E. N. Skinner, International Nickel Co., Inc.

Preliminary rupture data on Inconel "X" at 1350 and 1500 F. in an oxidizing atmosphere containing 0.1 and 1.0 per cent sulfur dioxide, indicate no appreciable deterioration in strength for tests of more than 1000 hr. duration. The influence of similar atmospheres on the rupture properties of Inconel at 1800 F. appears to be more damaging when the atmosphere contains a small amount of water vapor than when dry. On the other hand, at this temperature, the presence of water vapor in a sulfur dioxide-free air atmosphere causes an improvement in the rupture strength of Inconel.

Hydrogenizing Reactions of Gases on Metals at Elevated Temperatures. C. A. Zapffe and F. K. Landgraf, Consulting Metallurgists, Baltimore, Md.

Hardenable stainless steels are heat treated in atmospheres containing varying amounts of water vapor, and the angle of fracture in a specially designed bend test is then used to measure the damage caused these steels by hydrogen obtained from the metal-steam reaction. The investigation verifies the theory of the "hydrogen potential," published earlier. Steels which endure a full bend after hardening in a normal air atmosphere fail at a relatively low angle when steam is admitted; and steels which fracture with ordinary treatment can attain a full bend when special measures are taken to remove steam from the heat-treating atmospheres.

Oil Ash Corrosion of Metals at Elevated Temperatures. C. T. Evans, Jr., The Elliott Co.

Numerous metals of interest to gas turbine builders were exposed to "fired" Bunker C oil ash from several sources, at temperatures ranging from 1000 through 1500 F. Severe corrosion of most of the metals, including those commonly used in gas turbine construction, was encountered with some of the ashes.

Many coatings for metals were tried and there are indications that some of these coatings are protective. In addition, an attempt has been made to determine the constituents in the ashes which cause them to be "active" or corrosive. Experiments were conducted with "additives" in an attempt to neutralize the ashes.

Stress to rupture tests at 1350 F. were made with S-588 and 19-9DL alloy in contact with one ash of commercial interest.

Oral Presentation. W. N. Harrison, National Bureau of Standards.

Monday, June 26 8 p.m. Second Session

Held Simultaneously with the Third Session

Methods of Testing, Quality Control, Appearance, and Metallography

Report of Committee E-1 on Methods of Testing. J. R. Townsend, Chairman.

Report of Committee E-11 on Quality Control of Materials. H. F. Dodge, Chairman.

Report of Committee E-12 on Appearance. M. Rea Paul, Chairman.

Study of Deformation at High Strain Rates Using High-Speed Motion Pictures. Herbert I. Fusfeld and Josephine Carr Feder, Pitman-Dunn Laboratory, Frankford Arsenal.

The technique of using high-speed motion pictures to study the geometry of deformation of tensile specimens at drawing speeds is discussed. Preliminary data are used to give curves of the sharpness of the neck *versus* strain. These are used to correct for the true uniaxial tensile stress in comparison with results of Bridgman. It is shown that a change in the strain rate affects the geometry of the neck appreciably in contrast to the small change in tensile strength.

Effect of Variations in Notch Acuity on the Behavior of Steel in the Charpy Notched-Bar Test. N. A. Kahn, E. A. Imbembo, and F. Ginsberg, New York Naval Shipyard.

This paper presents and discusses data on the effects of variations in the root radius of the notch in Charpy V- and keyhole-notch specimens on the energy absorption level and location of the transition temperature region of a number of steels. The principal objective was to establish tolerances for the root radius of the V-notch for which no standards exist at the present time. The materials used in the investigation consisted of Navy medium and high-tensile steels and S.A.E. 1045 and 4620 steels, heat treated to tensile levels of approximately 60,000, 70,000, 85,000, 110,000, or 155,000 psi. For each steel and condition, energy-temperature relationships were established for V-notch radii of 0.006, 0.0075, 0.009, 0.010, 0.011, 0.013, 0.015, 0.017, and 0.021 in. and for keyhole diameters produced by Nos. 46, 47, and 48 drill sizes. The effect of polishing the root of the standard 0.010-in. radius V-notch was

also investigated. Equipment and techniques for preparing the notches and conducting the tests are described.

The Influence of Specimen Dimension and Shape on the Results in Tension Impact Testing. D. S. Clark and D. S. Wood, California Inst. of Technology.

A number of papers have been presented to reveal the influence of impact velocity on the tensile properties of materials. Most investigators have not reported the existence of a critical impact velocity. This paper presents data to show that it is necessary to maintain a ratio of specimen length to diameter of at least 13 in order to clearly reveal a critical velocity. The results of tests are reported to show that for a constant cross-section area the shape of the cross-section of the specimen does not alter the tensile impact characteristics of a material.

The Influence of Strain Rate on Some Tensile Properties of Steel. D. S. Clark and P. E. Duwez, California Institute of Technology.

The inability of impact tests to reveal the true influence of strain rate on the tensile properties is demonstrated. The fundamental requirements of a device by which strain rate effects can be studied are considered and the details of a machine that has been constructed are presented. The results of static and strain rate tests up to a rate of about 200 in. per in. per sec. are presented and discussed for three different steels. The specimens for these tests were taken from plates. The results show that the proportional limit of these materials increases to a value corresponding to the ultimate strength at a strain rate of between 40 and 80 in. per in. per sec. The ultimate strength for all materials tested increases with increasing rate of strain up to a rate of about 100 in. per in. per sec. and then is not affected appreciably.

A Direct Explosion Test to Evaluate Load Carrying Capacity of Welded Steel Structures. G. S. Mikhalapov, Metallurgical Research & Development Co. Inc.

Instances of failures, at stress levels well within design limits, of structures fabricated from steel plate 1/2 in. and thicker, which appear to be caused by low ductility exhibited by some materials in presence of severe stress concentrations and stress gradients, indicate the need of investigating behavior of materials under triaxial tension. A test utilizing an end blow of a column of explosive has been developed which, it is believed, simulates a state of traixial tension found at points of stress concentration in areas of steep stress gradient and thus permits evaluation of performance of materials when fabricated into structures containing notches and other stress concentrating geometries.

Tensile Properties of Some Aircraft Structural Materials at Various Rates of Loading. Richard F. Klinger, Wright-Patterson Air Force Base.

The effect of rate of loading in tension was determined at room temperature on nonmetallic and metallic aircraft structural materials. Stress-strain curves and ultimate strength values were obtained over the range of times to reach yield or ultimate strengths of 0.003 sec. to 2 hr., and rate of loading—strength relationships are presented. The results indicate a pronounced increase of ultimate and yield strength values with increased rate of loading for plastic materials such as polymethyl methacrylate cast sheet, cotton fabric base phenolic laminate, and glass fabric base polyester laminate. There was also a marked increase in initial modulus of elasticity with increase in rate of loading for the polymethyl methacrylate material. The test results for the metals, bare 24S-T and bare 75S-T aluminum alloys showed little change in yield strengths with respect to rate of loading.

A Method for Making Tension Tests of Metals Using a Miniature Specimen. R. L. Templin and W. C. Aber, Aluminum Research Laboratory.

Occasionally it is necessary to determine the tensile properties of metal products when only small samples are available or when the dimensions of pieces in one or two directions are such as to preclude the use of tensile test specimens of the usual sizes.

This paper describes a method for making tension tests of metals using a miniature specimen having a reduced section 0.05 in. in diameter and an over-all length of 3/4 in. The method for determining yield strength when using the miniature specimen is described for metals whose modulus of elasticity values have been determined previously. Suitable tension shackles and deformation measuring apparatus for the specimen are described in considerable detail. Results from tension tests of eight different sizes of specimens ranging from 0.5 to 0.05 in. in diameter are given to show the effect of the size of test specimen upon the results obtained for one material.

Monday, June 26 8 p.m. Third Session

Held Simultaneously with the Second Session

Symposium on Effect of Sigma Phase in the High Temperature Properties of Metals

Although the existence of the sigma phase in chromium-iron-nickel alloys has been known for over 20 years, the past five years have seen an increasing interest on the part of users of metals at elevated temperature in its occurrence, identification, and effects. So widespread has this interest become that researchers embarking on investigation of some aspect of the problems which have arisen are likely not to find the work they have planned a duplication of what is already underway elsewhere. The insidious nature of the phase makes a complete understanding of the conditions which promote its occurrence and of methods of controlling its effects on the properties essential to further progress in the development of alloys for service at high temperatures. The Research Panel of the Joint Committee on the Effect of Temperature on the Properties of Metals has been cognizant of the considerable amount of research going on at the present time on problems posed by the existence of sigma. Long as the existence of sigma has been known, its precise crystallographic structure is still unknown. Definite identification of the phase under the microscope is still uncertain even in many instances where its presence is clearly indicated by thermal history, composition, and other methods of testing. The limits of chemical composition within which sigma may form are not clearly defined. This Symposium was therefore organized in order to encourage those having research underway to present their progress, trends, and problems for discussion before a group having a common sympathetic interest in this somewhat baffling, not well-understood constituent of many of our heat-resistant alloys.

Identification and Mode of Formation and Re-Solution of Sigma Phase in Austenitic Fe-Cr-Ni Steels. E. J. Dulis and G. V. Smith, U. S. Steel Corp.

A comprehensive investigation of the etching characteristics of the several phases occurring in austenitic stainless steels, supplemented by X-ray diffraction and magnetic permeability studies, has suggested procedures by which the sigma, carbide, and ferrite phases can be differentiated, with certain exceptions, under the microscope. The mode of formation and re-solution of sigma was observed, and transient formation of ferrite was detected during re-solution of sigma at a temperature above its stable range.

Sigma Phase in Several Cast Austenitic Steels. V. T. Malcolm and S. Low, Chapman Valve Manufacturing Co.

The formation of the sigma phase in six cast austenitic steels was investigated by means of room temperature and elevated temperature impact testing, X-ray diffraction and metallorgaphic procedures.

Sigma phase was identified in the three 18–8 type steels investigated. Although the three 16–35 type steels were embrittled after elevated temperature exposure, no conclusive identification of sigma in these steels was obtained.

Transition temperatures, based on 50 per cent ductile fractures, were obtained for four of the six steels investigated.

X-ray Study of the Sigma Phase in Various Alloy Systems. Pol Duwez and Spencer R. Baen, California Institute of Technology.

This paper presents a critical review of the X-ray diffraction data of the sigma phase in the binary alloys of iron, cobalt, nickel, chromium, and vanadium. Although the crystal structure of the sigma phase is still unknown, a tentative tetragonal unit cell is suggested to describe the structure, at least as a first approximation. On the basis of this cell the lattice parameters of the various binary sigma phases are computed. The case of a ternary sigma solid solution in the iron-chromium-molybdenum system is also discussed and the influence of molybdenum on the lattice parameter of sigma is described. A short discussion is finally given on the occurrence of the sigma phase in binary alloys and its relation to atomic diameter and crystal structure of the two component metals.

Sigma Phase in Chromium-Molybdenum Alloys with Iron or Nickel. John W. Putman, N. J. Grant, and D. S. Bloom, Massachusetts Institute of Technology.

Because the brittleness of chromium-base alloys for high-temperature duty was believed to be due to sigma formation, research was undertaken to study the formation of sigma in simple alloys of chromium, molybdenum, and iron.

Late in May each member and committee member will receive a reservation form for the Annual Dinner and Luncheons. It should be returned promptly.

The experiments indicate that molybdenum increases the high-temperature stability of sigma in iron-chromium alloys, and that the sigma phase in the 60 Cr, 25 Mo, 15 Fe alloy is stable at 1100 C. With regard to this alloy, the temperature effect is such that at lower temperatures the tendency for the formation of sigma is increased provided that sufficient time be allowed for the transformation.

The Tetragonality of the Sigma Phase in the Iron-Chromium System. L. Menezes, J. K. Roros, and T. A. Read Columbia University.

Single crystal specimens of the 50 Fe-50 Cr sigma phase were prepared by isothermal transformation of coarse-grained ferrite of this composition at 775 C. In some cases single grains of ferrite transformed to single crystals of sigma phase, which could then be isolated by careful fragmentation of the brittle sample. Back-reflection Laue diffraction patterns were prepared, and the specimen fragments selected which yielded the best patterns. These patterns revealed a four-fold symmetry axis and two two-fold axes othogonal to it and to each other, characteristic of tetragonal crystals with the Laue symmetry 4/mmm. Even in the best samples crystal imperfections existed which led to diffuseness and multiplicity of the Laue pattern spots.

(Continued in Sixth Session)

ROUND-TABLE DISCUSSION ON HEAVY FORGINGS—SPONSORED BY GAS TURBINE PANEL OF JOINT COMMITTEE ON EFFECT OF TEMPERATURE—TUESDAY, JUNE 27, 9 A.M.

Tuesday, June 27 9 a.m. Fourth Session

Symposium on the Role of Nondestructive Testing in the Economics of Production

Report of Committee A-7 on Malleable-Iron Castings. W. A. Kennedy, Chairman.

Report of Committee E-7 on Nondestructive Testing. J. H. Bly, Chairman.

Symposium on the Role of Nondestructive Testing in the Economics of Production

A symposium to acquaint engineers and management with the advantages and uses of nondestructive testing, sponsored by A.S.T.M. Committee E-7 on Nondestructive Testing.

Papers by leading authorities in the field survey the wide range of applications of all the nondestructive testing and inspection methods and show how proper use of them can reduce production costs and improve product quality. The testing methods covered include radiography, ultrasonics, magnetic particle and liquid penetrant inspection, and magnetic analysis.

Six papers are presented in two sessions. The first two papers are of an introductory nature, one covering the basic principles underlying the important nondestructive test methods, and the other discussing typical discontinuities revealed by nondestructive testing.

The remaining four papers deal with the use of nondestructive testing for castings inspection, weldments inspection, wrought products inspection, and for special inspection problems. The papers discuss the economics of the various methods and point out where in each field of application the tests can be used to advantage as well as where they should not be applied.

A Basic Guide for Management's Choice of Nondestructive Tests. Robert C. McMaster and Samuel A. Wenk, Battelle Memorial Institute.

Twelve basic types of nondestructive tests are summarized and classified by the nature of the energy field established. The significant technical features of each method are illustrated. The literature and patent art has been surveyed and the information classified by methods of testing. Important operating features have been tabulated. The nature, critical features, and possible applications of nondestructive tests are discussed with references to existing commercial instruments. The principle of operation of each nondestructive test method is briefly stated, including the novel features and applications of the significant patents.

Defects or Discontinuities That Can Be Revealed in Cast and Wrought Metal Products by Nondestructive Tests. Kent R. Van Horn, Aluminum Company of America.

The Economics of Castings Inspection. J. W. Juppenlatz, Lebanon Steel Foundry.

A general discussion on the merits of diversified methods of nondestructive testing applicable to all grades of castings. Preferable test procedures employed for miscellaneous cast products with relation to end uses. Refinements of testing procedures and interpretation of results according to acceptable standards which are often poorly understood. Casting quality improvement as promoted by nondestructive inspection. Economic factors which dictate to a large extent the amount of nondestructive testing for cast products.

(Continued in Seventh Session)

Tuesday, June 27 12.15 p.m. Fifth Session

Luncheon Session—President's Address, Report of Board of Directors, Award of Honorary Memberships, Introduction of New Officers

Ladies are cordially invited

Tuesday, June 27 2.30 p.m. Sixth Session

Held Simultaneously with the Seventh Session

Symposium on Effect of Sigma Phase in the High-Temperature Properties of Metals (*Continued*)

The Formation of Sigma Phase in 17 per cent Cr Steel. J. J. Heger, Carnegie-Illinois Steel Corp.

By using cold work and extended heating periods at 1050 F., sigma phase has been formed and identified in 17 per cent chromium, type 430 stainless steel. These results indicate that the present iron-rich boundaries of the alpha plus sigma region in the iron-chromium diagram must be shifted to lower chromium contents.

The Effect of Prolonged Exposure at Elevated Temperatures on the Microstructure and Mechanical Properties of AISI Type 310 Stainless Steel. G. N. Emmanuel, Babcock & Wilcox Tube Co.

During the course of this investigation it was found that the temperature range in which sigma phase is formed in type 310 material is 1100–1600 F. Cold worked 25 chromium-20 nickel alloy exhibits not only a higher rate of sigma formation but also a broader temperature range of sigma stability, 1000–1600 F., than that indicated by annealed material. Some evidence is presented to indicate that increasing grain size leads to reduced susceptibility to sigma precipitation. A semiquantitative measure of the amount of sigma phase noted after various time-temperature conditions is included.

X-ray diffraction means are used to identify the sigma phase and a review of several metallographic identification methods is also presented.

The Formation of Sigma and Its Influence on the Behavior of Stabilized 18–8 Cr-Ni Steels in Concentrated Nitric Acid. R. S. Stewart and Stephen F. Urban, National Lead Co.

Sigma phase, rather than chromium carbide precipitation, was found to be responsible for the low-corrosion resistance of "sensitized" type 321 stainless steel in boiling 65 per cent nitric acid. Data are presented to show the influence of both chemical composition and prior heat treatments on the formation of sigma during "sensitizing" and the resulting corrosion resistance in boiling 65 per cent nitric acid. Practical means of producing type 321 commercial steels with acceptable low corrosion rates in the "sensitized" condition are given.

Some Notes on the Structure and Impact Resistance of Columbium-Bearing 18–8 Steels After Exposure to Elevated Temperatures. W. O. Binder, Union Carbide & Carbon Research Labs.

The influence of columbium on the impact properties of 18–8 steels has been studied in steels containing 8 to 16 per cent nickel and to 3 per cent columbium. The addition of more than 2 per cent columbium decreases the toughness of the steel in the annealed condition due to the formation of M_6C carbide and the compound Fe_3Cb_2. Long heating at 650 and 870 C. has no significant influence on impact toughness of steels containing up to 2 per cent columbium but it is more detrimental to higher columbium steels. Positive X-ray identification of sigma phase was obtained after long periods at 650 C. over the range 8 to 16 per cent nickel and 0.75 to 3 per cent columbium. However, the steels do not form large amounts of sigma even though strained at elevated temperatures.

Observations of the Effect of Sigma on the Mechanical Properties of Columbium Stabilized Weldments in Austenitic Stainless Steels. F. W. Schmitz and M. A. Scheil, A. O. Smith Corp.

A summary of the investigation of 13 weldments in 1½-in. thick T347 stainless steel on the basis of heat treatments given for stress removal reveals that ductility of all weld metal tension test bars is affected by the following variations:

1. Maximum ductility of 30 per cent and over is obtained in the "as-welded" condition with ferrite content between 3 and 8 per cent when no sigma is present.
2. Ductility varying between about 10 to 30 per cent is obtained after heat treatments producing sigma contents from 5 to 1 per cent.
3. Weld metal with ferrite in the as-deposited condition does not always sigmatize to the fullest extent possible.
4. The size and distribution of the sigma phase varies the ductility. Larger particles of sigma in a segregated pattern are more effective in lowering ductility.
5. Variations of welding techniques such as thin and thick weld layers and peening effect, the ductility only in so far as the amount of sigma produced on heat treatment.

The Occurrence of the Sigma Phase and Its Effect on Certain Properties of Cast Fe-Ni-Cr Alloys. J. H. Jackson, Battelle Memorial Institute.

Slightly over half of the production of heat-resisting castings is from alloy types which may contain the sigma phase provided the compositions of the alloys are not closely controlled. In many instances better properties for these alloys are obtained if sigma phase in these alloys is eliminated, or at least limited to relatively small quantities. In a recently developed test, it was noted that sigma-free, HH alloys (cast 26 per cent chromium-12 per cent nickel type) were much less susceptible to cracking and distortion than sigma-bearing alloys of the same type. The stress-rupture properties of the HK alloy (cast 26 per cent chromium-20 per cent nickel type) are improved when the composition is controlled to reduce the tendency toward formation of the sigma phase.

Report of Committee E-4 on Metallography. L. L. Wyman, Chairman.

The report of Subcommittee XI on Electron Microstructure of Steel, G. E. Pellissier, Chairman, will include a description of the investigation of the microstructures of eutectoid steel, correlating the light and electron microscopes.

Jt. Committee on Effect of Temperature on the Properties of Metals. E. L. Robinson, Chairman.

Tuesday, June 27 2.30 p.m. Seventh Session

Held Simultaneously with the Sixth Session

Symposium on the Role of Nondestructive Testing in the Economics of Production (*Continued*)

The Economics and Practical Application of Cobalt 60 for Weldment Inspection. W. Schwinn, Babcock & Wilcox Co.

The industrial application of Cobalt 60 in the inspection of steel weldments is investigated in actual practice by means of a comparison of radiographs taken with this source and with X-rays and gamma rays. Radiographs which have been exposed with variable X-ray voltages in the range of 250 to 1000 kv. are studied and compared to similar exposures with Cobalt 60 and gamma rays in the range of plate thicknesses of 1 to 4 in. In order to demonstrate not only the relative sensitivity of these sources and also the technique required, the economics, exposure times, and sensitivity charts covering these results, are also presented

The Economics of Wrought Steel Inspection. C. D. Moriarty, General Electric Co.

The economic value of nondestructive testing to the wrought steel user is discussed. The role this type of testing has in the user's manufacturing cycle, and its relation to the saving of manhours, which would otherwise be wasted on defective material, is emphasized. "The right test at the right time" is the economic theme. The part ultrasonics, and the testing of material in motion, has in the saving of manhours is discussed in greater detail because of their relative newness, and adaptability to the testing of wrought steel in the early stages of the manufacturing cycle

The Economics of Special Inspection Problems. L. W. Ball, Naval Ordnance Laboratory.

Tuesday, June 27 8 p.m. Eighth Session

Marburg Lecture, Dudley Medal, and Awards

Marburg Lecture—Chemical Spectroscopy—Wallace R. Brode, National Bureau of Standards

The purpose of the Edgar Marburg Lecture is to have described at the annual meetings of the Society, by leaders in their respective fields, outstanding developments in the promotion of knowledge of engineering materials. Established as a means of emphasizing the importance of the function of the Society of promoting knowledge of materials, the Lecture honors and perpetuates the memory of Edgar Marburg, first Secretary of the Society, who placed its work on a firm foundation and through his development of the technical programs brought wide recognition of the Society as a forum for the discussion of properties and tests of engineering materials.

Charles B. Dudley Medal to B. J. Lazan.

Richard L. Templin Award to D. S. Clark and D. S. Wood.

Sam Tour Award to O. B. Ellis.

(See News Article on Lecture in April BULLETIN, No. 165, p. 11)

Wednesday, June 28 9.30 a.m. Ninth Session

Held Simultaneously with the Tenth Session

Effect of Temperature

The Effect of Various Treatments on the Fatigue Strength of Notched S-816 and Timken 16-25-6 from Room Temperature to 1200 F. W. E. Jones and G. B. Wilkes, Jr., General Electric Co.

A rather extensive program has been undertaken to determine the fatigue strength of notched specimens of S-816 (a cobalt base alloy) and Timken 16-25-6 (a highly alloyed iron base alloy) from room temperature to 1200 F. Various corrective treatments were tried, such as shot peening, coining, and heat treating, to improve the notched strength. Improvements in the order of fivefold were obtained by shot peening, the effect being less as the test temperature is raised. Several general conclusions can be drawn regarding notches and treatments to reduce their damaging effect which should be of value to designers.

Hardened Alloy Steel for Service Up to 700 F. G. V. Smith, W. B. Seens, and E. J. Dulis, U. S. Steel Corp.

This paper describes the properties of two steels, 4340 and 0.40 C. NiCrMoV, quenched and tempered to 43 C Rockwell hardness, which were tested in tension at 75, 500, 600, and 700 F., in compression at 75 F., for creep-rupture strength at 500, 600, and 700 F., and for Charpy impact strength within the temperature range 75 to −315 F.

Interpretation of High Temperature Alloy Stress-Rupture Data. J. M. Cameron and W. J. Youden, National Bureau of Standards.

Stress-rupture data present special problems because (*a*) the number of conditioning factors preclude exhaustive exploration of all combinations of these factors and (*b*) the test results necessarily involve different test temperatures and loads so that the hours to rupture of specimens from different conditioning treatments are not directly comparable. The paper gives a method for comparing test results and considers the planned selection of combinations of conditioning factors for testing with a view of facilitating the statistical analysis.

Strength of Metals and Alloys at Elevated Temperatures. M. J. Manjoine, Westinghouse Research Labs.

The strength of metals and alloys and the factors which influence this strength are of paramount importance to the engineer who designs machines and to the metallurgist who develops new alloys and heat treatments for the parts of these machines. The results of tensile tests at 1200 and 1500 F. of a group of high-temperature gas turbine alloys are reported. These tests include creep and creep-rupture tests, constant strain rate tests, and high-speed impact tests. The strength of these alloys are shown for a range of strain rates of 10^{-6} to 10^{+6} per hr. The factors which influence the flow stress of a metal are discussed and a generalized flow-stress curve proposed. The short-time methods of comparing alloys and the limitations of these methods are reviewed.

Hardening of Austenitic Stainless Steels by Mechanical Working at Sub-Zero Temperatures. N. A. Ziegler and P. H. Brace, Westinghouse Research Labs.

It has been discovered that austenitic stainless steels, of approximate compositions of 12–30 per cent chromium and 11–20 per cent nickel, can be made unusually hard by plastically deforming them at sub-zero temperatures and thus promoting the gamma to alpha transformation. Hardness values thus obtained can be increased still further by a subsequent aging heat treatment of about 750 F. (400 C.).

Samples of suitable compositions have thus been hardened all the way through by rolling or wire drawing. Other physical properties are affected accordingly, so that in an 18 per cent chromium, 8 per cent nickel strip, rolled at −300 F. (−184 C.) and aged, tensile strength of 295,000 psi., yield stress of 290,000 psi., proportional limit of 264,000 psi., elongation fo 2.0 per cent, reduction of area of 24.8 per cent, and hardness of 60 V.P.N. have been obtained.

Effect of Temperature on the Mechanica Properties, Characteristics and Processin of Austenitic Stainless Steels. V. N Krivobok and A. M. Talbot, Internationa Nickel Co., Inc.

In this paper are presented the results o investigations dealing with the processin (such as rolling) of commercial austeniti stainless steels at sub-zero temperature showing that such processing enhances th mechanical properties and improves othe characteristics of the steels. The latte were represented by the most popular grade such as AISI 301, 302, 304, 310, and 347.

The mechanical properties at sub-zero an elevated temperatures were determined fo steels rolled according to normal practic (that is, at room temperature) and for steel rolled at sub-zero temperatures. The effect of sub-zero and elevated temperatures on th properties at room temperature were als determined.

The uncovered improvement in ductility characteristics, under conditions of sub-zer temperatures of steels strengthened by rolling, is discussed in terms of its relation t the forming processes.

Chromium-Base Alloys. W. L. Havekotte C. T. Greenidge, and H. C. Cross Battelle Memorial Institute.

Research is described on melting, casting and mechanical properties of chromium base alloys of the type 60 chromium-15 iron 25 molybdenum. A number of mold design and materials were used for making casting to provide suitable test material. The rup ture strength at 1600 F. of the alloy with 2 per cent titanium addition was considerably greater than for the best cobalt-base alloy but room-temperature ductility was very low Studies were made on the effect of melting and casting practice, of chemical composition and of heat treatment on room-temperatur shock resistance.

Wednesday, June 28 9.30 a.m. Tenth Session

Held Simultaneously with the Ninth Session

Symposium on Methods of Testing Soils Under Triaxial Loading

A most extensive symposium on testing soils under triaxial loading has been arranged by A.S.T.M. Committee D-18 on Soils for Engineering Purposes. Ten papers cover various fields of triaxial testing. These include papers on large-scale triaxial test equipment and procedures, shear characteristics of soils, interpretation of data, use of data in design, and performance correlation. Some of the papers which deal with subgrade design also bring out the use of triaxial tests in pavement design.

A Triaxial Apparatus for Testing Large Soil Specimens. Earl B. Hall, Corps of Engineers.

This paper presents the construction and operation of an apparatus to test, by triaxial methods, the shear characteristics of soil containing material passing the 3-in. sieve. It is the aim of this paper to present the problems arising from the design of an apparatus of this magnitude, and the method by which these problems were solved. Sketches of parts of the apparatus together with typical results of soils tested are also included.

Shear Testing at the Waterways Experiment Station. S. J. Johnson, Waterways Experiment Station.

The paper reviews very briefly the triaxial shear research program sponsored by the Corps of Engineers and discusses how the results of that program form the basis for the types of tests performed in the Soils Laboratory of the Waterways Experiment Station, Corps of Engineers for practical applications. In addition, practices developed for the design of earth embankments which indicate variations in water content and density and the shear strength are reviewed. The aim of the paper is not to discuss in funda mental fashion theories of shear testing, bu instead it attempts to summarize the type of tests actually performed in the Soil Laboratory in connection with foundatio problems.

New Developments in Triaxial Testin Methods for Partially Saturated Soils Donald W. Taylor, Massachusetts Institut of Technology.

Shear Characteristics of Remolded Eart Materials. A. A. Wagner, Bureau o Reclamation.

The results of several triaxial shear test performed on five different materials place at different densities and moistures are pre sented. By correcting the results for th measured pore pressure and interpretin failure by the maximum effective stress rati

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criterion, the "true" angle of friction is determined, and trends showing the effects of placement density and moisture on the "true" angle of friction are shown.

Triaxial Compression Conditions and the Interpretation of Test Results. Donald M. Burmister, Columbia University.

Consideration is given first to the objectives and the purposes of triaxial compression testing in order to provide basic information on the stress-strain and strength properties of soils for making soil investigations in connection with engineering works. Second, consideration is given to the fundamental concept of the "stress-conditioning" of the stress-strain and strength properties of soils under the initial stresses to which soils are subjected in the natural state or in the compacted state in embankments. This concept is basic in all of the strength testing of soils, and has a controlling influence on the essential test conditicns, which must be satisfied in order to have either (*a*) test results that are capable of complete analysis for use in the investigation of specific soil problems, or (*b*) testing results that have a direct and significant bearing upon a specific soil problem. The fundamental and practical importance of this approach is illustrated by triaxial compression test results, and by the interpretation and use of triaxial compression test data in the analysis of soil problems encountered in connection with engineering works.

(*Continued in Eleventh Session*)

Wednesday, June 28 2 p.m. Eleventh Session

Held Simultaneously with the Twelfth Session

Symposium on Methods of Testing Soils Under Triaxial Loading (*Continued*)

Triaxial Design Correlated with Flexible Pavement Performance in Kansas. H. E. Worley, Kansas State Highway Commission.

Kansas' experience in the design and construction since 1945 of approximately 375 miles of base course and flexible surface according to methods based on triaxial testing is discussed. A summary of results based on 14,000 tests is included. Methods of sampling, sample preparation, description of equipment, and procedures for testing are included. The application to the design of flexible pavements is fully covered, and the application to other design problems such as rigid pavements, slopes, and foundations is discussed briefly.

Application of Triaxial Compression Test Results to Highway Soil Problems. E. S. Barber and C. L. Sawyer, Bureau of Public Works.

The application of triaxial test results to the design of fill and cut slopes, flexible pavements, and bridge foundations is described. The results obtained by different methods of preparing the sample and methods of loading are presented. These include exploratory results on repetitional loading and the effect of the intermediate principle stress. Comparisons are made between triaxial and direct shear tests.

Triaxial Testing, Adapted to Soils, Flexible Base, and Foundations. R. J. Hank, Texas State Highway Department.

The paper gives the reasons for entering into triaxial testing of various soil materials and for designing special equipment to accomplish this purpose. The materials to be tested include disturbed, remolded soils, with and without aggregate, or flexible base, in which maximum particle size is limited to 2 in., and undisturbed cores of foundation materials. The specially designed equipment will be described and pictured. The procedure is defined in some detail in the interest of reproducibility.

There will be a brief discussion of the background of the procedure and the application of the test data to the design of flexible bases and to the analysis of foundation problems. Graphs and tables used in the interpretation are illustrated by line drawings.

Some Concepts Concerning Triaxial Compression Testing of Asphaltic Paving Mixtures and Subgrade Materials. H. E. Davis, University of California and F. N. Hveem, California Division of Highways.

Application of Triaxial Testing to the Design of Bituminous Pavements. Norman W. McLeod, Ottawa Department of Transport.

The use of the triaxial test for the rational design of bituminous paving mixtures is outlined. The influence of the rate of deformation employed for the triaxial test, on the reported stability values of bituminous mixtures is reviewed. It is demonstrated that data from the triaxial test enable an evaluation to be made of the amount of lateral support that bituminous pavements can develop under load in the field. Triaxial data make it possible to determine the influence of frictional resistance between pavement and tire and between pavement and base on the stability of bituminous pavements. It is shown that this factor has a very marked effect on the ability of bituminous pavements to support stationary and moving loads. The treatment of the subject matter is entirely quantitative and is accompanied by equations and illustrations.

Wednesday, June 28 2 p.m. Twelfth Session

Held Simultaneously with the Eleventh Session

Fatigue Testing

Report of Committee E-9 on Fatigue. R. E. Peterson, Chairman.

Effects of Grinding and Other Finishing Processes on the Fatigue Strength of Hardened Steel. L. P. Tarasov, Norton Co., and H. J. Grover, Battelle Memorial Institute.

This paper presents the results of an investigation of the effects of grinding and other finishing processes on the fatigue strength of a ball-bearing type steel, very similar to AISI-52100, at Rockwell hardness levels of C 45 and C 59. Grinding scratch direction was always parallel to the specimen length.

Reversed-bending tests of flat bars showed: (1) gentle grinding gave endurance limits as high as gentle grinding followed by careful polishing, (2) severe grinding reduced the endurance limits roughly 20–25 per cent, and (3) either tumbling or shot peening after grinding greatly increased the endurance limits.

Rotating-bending tests of round bars gave endurance limits about twice as high as reversed bending of flat bars of corresponding hardness. The endurance limits of round bars were affected relatively little by surfacing processes and the effects of a given process, if they were real, were not necessarily consistent for the two hardness levels.

In no case did gentle grinding prove detrimental to the fatigue properties.

Effect of Chromium Plating on the Endurance Limit of Steels Used in Aircraft. Hugh L. Logan, National Bureau of Standards.

Chromium plating reduced the endurance limits of both normalized and hardened (quenched and tempered) S.A.E. X4130 steels; the reduction was larger for the hardened steel. The endurance limits for steel of a given hardness decreased with increased plating bath temperatures. Baking of the plated steel, at temperatures up to 350 C., reduced the endurance limit; baking at 440 C. increased the endurance limit of the plated steel. However (for hardened steel) baking did not restore the endurance limit to that of the unplated steel. Damaging effects of chromium on the endurance limits of plated steels are attributed to stresses in the chromium and/or steel, which are increased by low-temperature baking but are relieved in part by baking at 400 to 440 C.

Combined Tension-Torsion Creep-Time Relations for Alcoa 2S-O. Joseph Marin, Pennsylvania State College, J. H. Faupel, E. I. du Pont de Nemours & Co., Inc., and L. W. Hu, Pennsylvania State College.

Many machine and structural parts are subjected to creep and a combined state of stress. Most experienced investigations on the creep properties of materials, however, have been made under conditions of simple stress. There have been only a few investigations reported on the creep-time relations of materials subjected to combined stresses. This paper gives the results of an investigation on the combined stress creep properties of Alcoa 2S-O. Combined states of stress were produced by subjecting thin-walled tubular specimens of circular cross-section to various combinations of axial tension and torsion. The minimum constant creep rates for various values of the stresses and for ratios of the biaxial principal stress from 0 to −1.0 were found to be in approximate agreement with values predicted theoretically using simple tension creep test results.

Effects of Anodic Coatings on the Fatigue Strength of Aluminum Alloys. G. W. Stickley and F. M. Howell, Aluminum Research Labs.

Anodic treatments of aluminum alloys are widely used because they provide increased resistance to abrasion and corrosion. While it is generally accepted that such coatings have no appreciable effect on the static properties, their effects on fatigue strength have been questioned. The results of tests of several anodic treatments on different aluminum alloys are presented and reference is made to the work of other investigators. While the thicker coatings were found to be slightly harmful under certain conditions, the effect of the thinner coatings, if any, was slightly beneficial.

The Reverting of Hard-drawn Copper to Soft Condition Under Variable Stress. John N. Kenyon, Princeton University.

Endurance tests carried out at room temperature on long lengths of hard-drawn copper wire show that "islands" of soft material may develop at, or near, the perimeter of the wire specimens. This softening effect occurred in some 30 per cent of the heats tested at room temperature and in practically every heat when the endurance tests were carried out at 70 C.

It is believed that transmission line failures usually attributed to mechanical defect in wire, are a direct result of this unusual softening behavior.

Report of Committee B-4 on Electrical Heating, Resistance, and Related Alloys. S. A. Standing, Chairman.

Wednesday, June 28

Cocktail Party 6.30 p.m. and Annual Meeting Dinner 7.30 p.m.

The Philadelphia District, through its Council, is acting as the official host for this Annual Meeting. It has arranged a Cocktail Party and informal Dinner at which there will be some outstanding entertainment. The Council felt that the members might welcome some period during the Annual Meeting of a distinctly social nature and with the approval of the Society officers, has arranged this feature. The Cocktail Party will be on a "dutch" basis, starting at 6:30 p.m. in the Carolina Room, with Dinner to follow at 7:30. There is to be dinner music and following this, three or four interesting and coordinated entertainment acts, by outstanding performers, will take place. A form for dinner reservations will be mailed to members later in May.

The Philadelphia District Council is also arranging for Ladies' Entertainment, and is including the dinner in this program since the performances will be of interest not only to the members, but to their wives and families.

Thursday, June 29 9 a.m. Thirteenth Session

Held Simultaneously with the Fourteenth and Fifteenth Sessions

Non-Ferrous Metals, Spectroscopy

Report of Committee E-2 on Emission Spectroscopy. B. F. Scribner, Chairman.

Report of Committee B-2 on Non-Ferrous Metals and Alloys. Bruce W. Gonser, Chairman.

Report of Committee B-7 on Light Metals and Alloys, Cast and Wrought. I. V. Williams, Chairman.

Magnesium-Cerium Wrought Alloys for Elevated-Temperature Service. K. Grube, J. A. Davis, and L. W. Eastwood, Battelle Memorial Institute.

A systematic study has been made of about 195 heats of magnesium-cerium wrought alloys by making tension tests at room temperature and at 600 F., and creep tests at 600 F. Manganese up to 1 per cent or more and cerium up to 2 per cent are very beneficial. The alloy of optimum composition appears to be as follows: cerium (rare earths)—2 per cent, manganese—1 to 1.5 per cent, and nickel—0.2 per cent. The compositional limits were not established. This alloy has tensile and creep properties at 600 F. which, on a strength-weight basis, are appreciably better than those of 18S-T and 32S-T alloys of aluminum frequently recommended for elevated-temperature service.

Magnesium-Cerium Cast Alloys for Elevated-Temperature Service. K. Grube and L. W. Eastwood, Battelle Memorial Institute.

About 350 heats of magnesium-cerium alloys, most of which contained other elements, have been prepared and studied. The evaluation of the compositions was based on the following tests: (1) tension tests at room temperature, (2) tension tests at F., (3) creep tests at 600 F., using a 2500 psi. load, and (4) macro- and microexaminations.

Six per cent cerium (rare earths) was selected for study as a compromise between cheaper and lower density alloys of lower cerium content, on the one hand, and higher strength alloys of still higher cerium content, on the other. Manganese was also employed in most of the alloys because of its beneficial effects on tensile properties and creep resistance at 600 F. The alloy of optimum composition tentatively selected is as follows: cerium (rare earths)—6 per cent, manganese—0.8 per cent, nickel—0.2 per cent, and tungsten—0.02 per cent.

Aluminum-6 per cent Magnesium Alloys for Elevated-Temperature Service. L. W. Eastwood, Webster Hodge, and C. H. Lorig, Battelle Memorial Institute.

As a result of a systematic study of aluminum-base alloys containing magnesium, the following casting alloy has been developed for elevated-temperature service: magnesium—6 per cent, manganese—1 per cent, copper—1.5 per cent, vanadium—0.1 per cent, zirconium—0.25 per cent, titanium—0.08 per cent, beryllium—0.005 per cent, and aluminum—99.5 per cent balance. This alloy is not appreciably adversely affected by stabilization at temperatures up to 700 F., has low density, good resistance to corrosion, good machining characteristics, and, after stabilization at 600 F., has very high tensile properties. As compared with 142 or Y alloy castings, it has appreciably lower thermal conductivity and somewhat lower resistance to creep at 600 F. Although the above composition has considerably better resistance to creep than previously known 6 per cent magnesium casting alloys, still further improvements in creep resistance may be possible.

Report of Committee B-1 on Wires for Electrical Conductors. J. H. Foote, Chairman.

Report of Committee B-8 on Electrodeposited Metallic Coatings. C. H. Sample, Chairman.

Report of Committee B-6 on Die-Cast Metals and Alloys. J. R. Townsend, Chairman.

Late in May each member and committee member will receive a reservation form for the Annual Dinner and Luncheons. It should be returned promptly.

Thursday, June 29 9 a.m. Fourteenth Session

Held Simultaneously with the Thirteenth and Fifteenth Sessions

Steel, Ferro Alloys, Chemical Analysis

eport of Committee A-9 on Ferro Alloys. W. C. Bowden, Jr., Chairman.

eport of Committee A-1 on Steel. N. L. Mochel, Chairman.

eproducibility of Results of Tensile Tests on Specimens Prepared from Cast Steel Coupons. Harry A. Schwartz and W. Kenneth Bock, Nat. Malleable and Steel Castings Co.

Various types of the coupons used by the teel castings industry are discussed and illustrated. Data are recorded showing the egree of reproducibility of the usual static ensile properties of Grade "B" steel or etermined on test coupons of several designs.

The results of single tests on the average f a small number of tests are shown not to be n adequate measure of the mechanical roperties of a given steel cast in a given orm of coupon.

ome Effects of Austenitic Grain Size and Metallurgical Structure on the Mechanical Properties of Steel. T. J. Dolan and G. M. Sinclair, University of Illinois.

Studies were made of S.A.E. 1045, 2340, nd 3140 steels to determine the changes in iechanical properties which accompanied a rge increase in the austenitic grain size. he steels were heat-treated to produce mirostructures of pearlite, tempered martensite, nd a "mixed" structure of tempered marensite plus free ferrite; all steels were temered to a final hardness of 100 Rockwell B. hanges in the tensile, fatigue, and V-notch harpy impact properties which accomanied an increase in the austenitic grain ze, are discussed on the basis of the metalrgical structure involved.

ockwell C. Hardness on Cylindrical Steel Specimens. Frank W. Hussey, Pitman-Dunn Lab., Frankford Arsenal.

The trends of errors involved in determining Rockwell C Hardness on small-diameter cylindrical steel surfaces are reported. Results are announced of a test consisting of more than 2800 hardness readings on steel specimens of 8 diameters and in 10 steps of hardness from Rockwell C 20 to 65 in each size group. The plotted deviations of the apparent hardness, taken on curved surfaces, from the "true" values of flat areas show line relationships of such slight curvatures that straight line averages are considered sufficiently accurate for all practical purposes. Correlation curves are presented which are used to obtain actual Rockwell C hardness values from those obtained on cylindrical surfaces of diameters from ¼ to 1¼ in.

Welding Characteristics of Open Hearth and Bessemer Seamless Pipe. A. B. Wilder, W. B. Kennedy, and F. W. Crouch, National Tube Co.

The purpose of this paper is to discuss the welding characteristics of A.S.T.M. Specifications A-53 Grade B seamless pipe and in particular the properties which are related to deoxidation practice and steel-making process. Silicon-killed and silicon-aluminum killed basic open hearth and deoxidized acid bessemer steels were investigated.

The properties of girth and bead welds were studied. The material investigated met welding requirements of the A.S.M.E. Boiler Construction Code. A new type of weldability test, internal structure, hardness, cracking susceptibility, impact properties, and hardenability results are discussed.

Welds Between Dissimilar Alloys in Full Size Steam Piping. R. U. Blasser and F. Eberle, Babcock & Wilcox Co.

A laboratory test under simulated service conditions in 10-in. steam piping is described. The specimen has two austenitic weld metal joints between a Croloy 2¼ alloy and both forged and cast austenitic materials. Operation has been at 1100 F. temperature with internal pressure 1500 psi., and has included approximately 50 week-end shutdowns to atmospheric conditions. After 4631 operating hours at these test conditions, incipient failure was detected by radiographic means. Metallurgical examination of the failure is included. An analysis is made of contributing factors which include stresses due to thermal expansion as well as steam pressure, temperature, time, environmental atmosphere, design, and metallurgical condition of the material.

Some Considerations in the Joining of Dissimilar Metals for High-Temperature Service. O. R. Carpenter, The Babcock & Wilcox Co.

This paper relates to the metallurgical factors, the performance, and fabrication of dissimilar metal joints as may be employed in high-pressure, high-temperature steam service. It has been recognized by those who have considered or who have used this construction that expansion stresses existing between a ferritic material and an austenitic material might present unknown problems in service. An investigation of expansion stress effects on dissimilar metal joints, begun several years ago, has led to the necessary consideration of additional factors which were found to be present when a dissimilar metal joint is operating at high temperature, under high stresses in a cyclic manner. These are basically metallurgical ones. They are shown to be dependent upon the time, the temperature, and the combined stresses. Under some conditions, laboratory tests show that failure occurs in a carbon depleted region of the heat-affected zone of the weld. Cyclic conditions, oxide penetration, and metallurgical or mechanical notches as may occur under some operating or fabricating conditions, speed the time to failure. Failures of field welds of dissimilar metals under severe operating conditions are shown as examples.

Report of Committee E-3 on Chemical Analysis of Metals. D. R. Evans, Chairman.

Thursday, June 29 9 a.m. Fifteenth Session

Held Simultaneously with the Thirteenth and Fourteenth Sessions

Cement and Concrete, Roofing Materials

eport of Committee C-1 on Cement. F. H. Jackson, Chairman.

esting Cement-Base Paints and Dampproofers. William M. Spurgeon, American Fluresit Co.

Tests made on 25 commercial cement aints, many of which are used for damproofing masonry walls, show that they vary idely in porosity (water absorptions range om 1.8 to 65.1 per cent by weight) and 7-ay compressive strengths (0 to 3300 psi.). n general, high absorption values accomanied low compressive strengths and *vice ersa*.

The theory of dampproofing is discussed riefly, and the need for further development f a simple, short screening test to supplement weathering data for cement-base damproofers is shown. The need for establishing pecifications for these materials is also ointed out.

eport of Committee C-2 on Magnesium Oxychloride Cements. L. S. Wells, Chairman.

Report of Committee C-9 on Concrete and Concrete Aggregates. K. B. Woods, Chairman.

Exploratory Tests to Develop a Method for Determining the Air Content of Hardened Concrete. Alexander Klein, David Pirtz, and Milos Polivka, University of California.

Pulse Techniques Applied to Dynamic Testing. J. R. Leslie. Hydro-Electric Power Commission of Ontario.

Many of the difficulties inherent in present methods of dynamic testing can be overcome if pulse techniques are resorted to. In this method the velocity of propagations of an acoustical pulse through the material is measured. The pulse velocity so obtained is unaffected by size or shape of the specimen. An electronic pulse set developed primarily for testing concrete is described. A pulse generator and receiver are used, applied to opposite faces of the specimen. The time of travel of the pulse is measured electronically and from it the dynamic modulus of elasticity can be calucated. More than two years experience in testing laboratory specimens and mass concrete is described and the instrument's application to the testing of soils, rock, and wood are illustrated.

Method of Petrographic Examination of Aggregates for Concrete. Katharine Mather and Bryant Mather, Waterways Experiment Station.

A detailed description of the method for petrographic examination of aggregates for concrete as it has been developed for use by the Concrete Laboratories of the Corps of Engineers is presented. The differences in procedure which depend upon the nature of the sample submitted and the purposes of the examination are described. Suggestions are made concerning the features to be delineated, the amount of material to be examined, and the organization and presentation of the results of the examination. It is hoped that the information presented will serve to clarify the concept of what is

meant by petrographic examination of aggregates and, perhaps, ultimately, contribute to greater uniformity in the making of such examinations.

Report of Committee C-13 on Concrete Pipe. W. W. Horner, Chairman.

Report of Committee C-4 on Clay Pipe. J. C. Riedel, Chairman.

Report of Committee D-8 on Bituminous Waterproofing and Roofing Materials. J. S. Miller, Chairman.

Results on Testing Surface Waterproofers. F. O. Anderegg, John B. Pierce Foundation.

The methods of testing reported at the Detroit meeting have been applied to a large number of additional materials. The results obtained, reinforced by field observation support the previous analysis of the proble and indicate the usefulness of the metho that were proposed. Results reported he seem to show that three new types of surfa waterproofers, including certain resin emu sions, silicone solutions and sprayed-c stuccos, offer considerable promise. Th beneficial properties and the limitations of t different types are discussed with referen to the potential exposure hazards. Ease application and costs are also estimated.

Thursday, June 29 12.15 p.m. Sixteenth Session

Luncheon Session—Award of Merit, Recognition of 40- and 50-Year Members

Ladies are cordially invited

Thursday, June 29 2.30 p.m. Seventeenth Session

Held Simultaneously with the Eighteenth Session

Report Session—Building Materials

Report of Committee C-22 on Porcelain Enamel. W. N. Harrison, Chairman.

Report of Committee C-21 on Ceramic Whitewares. J. H. Koenig, Chairman.

Report of Committee C-19 on Structural Sandwich Constructions. A. G. H. Dietz, Chairman.

Report of Committee C-14 on Glass and Glass Products. E. W. Tillotson, Chairman.

Report of Committee C-18 on Natural Building Stones. L. W. Currier, Chairman.

Report of Committee C-15 on Manufactured Masonry Units. J. W. Whittemore, Chairman.

Report of Committee E-6 on Methods Testing Building Constructions. J. Liska, Chairman.

Report of Committee D-7 on Wood. L. Markwardt, Chairman.

Thursday, June 29 2.30 p.m. Eighteenth Session

Held Simultaneously with the Seventeenth Session

Report Session—Paint, Electrical Insulating Materials, Coal and Coke, Soap, Textiles

Report of Committee D-1 on Paint, Varnish, Lacquer, and Related Products. W. T. Pearce, Chairman.

Report of Committee D-16 on Industrial Aromatic Hydrocarbons. D. F. Gould, Chairman.

Report of Committee D-9 on Electrical Insulating Materials. C. T. Hatcher, Chairman.

Report of Committee D-5 on Coal and Coke. W. A. Selvig, Chairman.

Report of Committee D-12 on Soaps a Other Detergents. J. C. Harris, Cha man.

Report of Committee D-13 on Textile Ma rials. H. J. Ball, Chairman.

Thursday, June 29 8 p.m. Nineteenth Session

Symposium on Identification and Classification of Soils

Report of Committee D-18 on Soils for Engineering Purposes. E. J. Kilcawley, Chairman.

Symposium on Identification and Classification of Soils

The Symposium on Identification and Classification of Soils is sponsored by Committee D-18 on Soils for Engineering Purposes. In preparing its manual on Procedures for Testing Soils, Committee D-18 discussed the desirability of including with this manual, data on classification of soils. It was decided not to include this information in the manual, it being related to test methods only, but to present it in the form of a symposium to be issued as a separate pamphlet. Papers are being prepared by E. A. Willis, Bureau of Public Roads, D. M. Burmister, Columbia University, E. A. Abdun-Nur, Bureau of Reclamation, and Earl J. Felt, Portland Cement Assn. The committee is hoping to secure one or two additional papers for presentation at the symposium.

Final titles and abstracts have been received for the following two papers:

Soil Classification for Highway Purpos E. A. Willis, Bureau of Public Roads.

This paper reviews the development of s classification methods as utilized by Bure of Public Roads, U. S. Department of Co merce, and many of the State highway partments.

These methods were conceived at a ti when few highway engineers had any kno ledge of the engineering properties of so One of the primary purposes of the origi highway soil classification was to provid relatively simple means whereby generali

nformation on soils could be passed on from he soils engineers to the engineers and inpectors who were directly concerned with he design and construction of the highways. This report points out that environmental actors such as climate, topography, drainge, etc., are equally important in determining the engineering properties of soils. A reiew is presented of the progress being made n the development of engineering soil maps hose "map units" will indicate the environental factors as well as the physical charcteristics revealed by laboratory tests.

An Appraisal of the Identification Approach in Soil Mechanics. Donald M. Burmister, Columbia University.

Identification places the emphasis not nly on accurately and completely identifying ndividual soils, but also on the careful, systematic, and precisely written and spoken identification and naming of soils, which convey definite and significant meanings. The identification approach recognizes the inherently variable and complex nature of soils and of the controlling conditions in engineering practice. The identification of soils is intended to accurately and completely disclose the inherent characteristics of soils which determine their behavior characteristics. Consideration is given briefly to the principles of identification and of naming soils. The practical use and importance of identification in soil investigations for engineering works is illustrated by the possibilities of more completely and accurately interpreting and comprehending past experiences with regard to what was expected and what really happened.

(*End of Symposium*)

Pilot Studies of Soil Density Measurements by Means of X-rays. D. Berdan and R. K. Bernhard, Rutgers University.

Pilot experiments have been made with soil samples in small containers to determine by means of X-rays first, the effect of soil densification on the X-ograph and second, the effect of densification on differential pressure cells buried in the soil samples. Characteristic X-ray images are presented, and some conclusions, with respect to the application of this method, are discussed.

This nondestructive X-ray method which leaves the soil sample completely unchanged, regardless of its state of densification, might become useful in cases where undisturbed soil samples cannot be obtained. A possible development for future field applications is suggested.

Friday, June 30 9.30 a.m. Twentieth Session

Plastics, Adhesives, Shipping Containers

eport of Committee D-14 on Adhesives. Frank W. Reinhart, Chairman.

eport of Committee D-20 on Plastics. G. M. Kline, Chairman.

he Measurement of Dynamic Modulus in Adhesive Joints. A. G. H. Dietz, G. M. Kavanagh, P. J. Closmann, and J. N. Rossen, Massachusetts Institute of Technology.

An experimental method is described for ieasuring a fundamental property of an dhesive, the dynamic modulus, without estroying the bond. By measuring the esonance properties of a specimen consisting f two metal bars cemented together end-toid and vibrating longitudinally, the dynamic odulus of the adhesive in the joint may be alculated. Measurements obtained by this ethod are presented for stainless steel bars emented with a phenol-formaldehyde, polyinyl-butyryl adhesive. For specimens that ave been subjected to excessive heating, a orrelation was found to exist between the ynamic modulus and ultimate bond rength.

ress Cracking of Polyethylene. R. H. Carey, Union Carbide & Carbon Corp.

The mechanical properties of polyethylene e compared with older, more common mateals. It is shown that polyethylene is not a ubber-like" or "elastomeric" material but ore nearly resembles some soft, non-ferrous etals. This comparison is inferred from its ystalline structure as determined by X-ray ffraction, its stress-strain diagram and the henomenon of "stress corrosion cracking." Data for specimens (containing a hole) sted in tension while immersed in various uids are reported. It is found that a soilled "brittle" fracture is produced by the esence of a hole and is accentuated by cerin fluids. These phenomena are associated with the stress-strain curve. Data are reported for several molecular weight resins.

Effects of Elevated Temperatures on Strength of Thermosetting Plastic Laminates. N. Fried and R. R. Winans, New York Naval Shipyard and L. E. Sieffert, Bureau of Ships.

This paper presents the results of one phase of a comprehensive investigation, being conducted at the Material Laboratory, New York Naval Shipyard, relating to the effects of exposure to elevated temperatures on the mechanical and electrical properties of certain laminated thermosetting plastic materials. This phase includes a study of the progressive effects of such conditioning on the flexural and compressive strengths of a glass-melamine and two types of phenolic laminate, as determined at the elevated temperatures. Temperatures ranged from 50 C. through 250 C. and periods of conditioning from 1 through 768 hr. Methods and special equipment for making measurements at high temperatures are described in detail. Results are discussed, criteria for determining the maximum operating temperature of the materials are set down, and a hypothesis is presented to explain observed behavior.

Outdoor Weather Aging of Plastics Under Various Climatological Conditions. S. E. Yustein and R. R. Winans, New York Naval Shipyard and H. J. Stark, Bureau of Ships.

The results obtained in an investigation of the effects of outdoor weather aging under widely different climates on a variety of plastic materials are reported. Five climatological regions are represented in the program which provides for exposure sites at (1) Panama Canal Zone (tropical); (2) New Mexico (dry desert); (3) New York Naval Shipyard (temperate); (4) Fort Churchill, Manitoba, Canada (subarctic); (5) Point Barrow, Alaska (arctic). The report covers exposures for 1, 3, 7 and 12 months. The program provides for exposures up to 3 yr; subsequent reports will cover 18, 24, 30, and 36 month exposures. The materials employed in the program include various types of clear transparent sheet plastics, laminated sheet materials, and molded materials, which are evaluated for a variety of physical properties after each exposure. On the basis of the data accumulated after the completion of the first year's exposure, it is possible to deduce the occurrence of a variety of effects that appear to be related to differences in the climatic and environmental conditions and in the exposure periods.

Report of Committee D-10 on Shipping Containers. T. A. Carlson, Chairman.

Report of Committee D-17 on Naval Stores. V. E. Grotlisch, Chairman.

Report of Committee D-6 on Paper and Paper Products. W. R. Willets, Chairman.

Rotary Screen for Separation of Shives from Mechanically Prepared Wood Pulp. H. W. Greider, R. A. MacArthur, and L. C. Gischig, Philip Carey Manufacturing Co.

The screen described in this paper was developed as part of a cooperative investigation by the members of the Asphalt Roofing Industry Bureau on the effect of shives in Asplund defiberated wood upon the weatherability and over-all quality of prepared roofings containing Asplund fiber. A wood shive is defined as a fiber bundle having a minimum lateral dimension and the screen was designed to separate fibers and fiber bundles according to their lateral dimensions rather than their lengths. The use of this screen in conjunction with the Bauer-McNett Classifier, which evaluates fiber lengths, affords substantially complete estimation of the physical character of mechanical wood pulp.

Friday, June 30 2 p.m. Twenty-first Session

Held Simultaneously with the Twenty-second and Twenty-third Sessions

Building Materials, Fire Tests of Materials

eport of Committee C-11 on Gypsum. L. S. Wells, Chairman.

eport of Committee C-7 on Lime. W. C. Voss, Chairman.

The Effect of Time and Temperature of Burning on the Properties of Quicklime Prepared from Calcite. J. A. Murray, H. C. Fischer, and D. W. Sabean, Massachusetts Institute of Technology.

Pure calcite, sized to pass a No. 10 sieve and to be retained on a No. 20 sieve, was calcined in an electrically heated rotary tube, which was provided with continuous feed and discharge. Over 40 calcinations were made, with maximum material temperatures varying from 1700 to 2400 F. and with over-all retention times varying from 47 to 470 min.

The density, porosity, surface area, and reactivity with water were determined on each of the resulting quicklimes.

Porosity, surface area, and reactivity with water are closely related. Highly porous limes have high surface area and a fast rate of reaction, while limes of low porosity are characterized by low surface area and slow reaction with water.

The results show that porosity of the quicklime is determined primarily by the rate of heating prior to and during calcination, while the heating conditions subsequent to calcination have relatively little effect. When material of this size required 35 min. or more to reach a temperature of 1700 F., the resulting quicklime was always highly porous, regardless of subsequent treatment. Quicklime calcined in increasingly shorter periods was correspondingly less porous.

Report of Committee C-17 on Asbestos-Cement Products. H. R. Snoke, Chairman.

Report of Committee C-8 on Refractories. R. B. Sosman, Chairman.

Report of Committee C-16 on Thermal Insulating Materials. Ray Thomas, Chairman.

Report of Committee E-5 on Fire Tests of Materials and Construction. A. L. Brown, Chairman.

Automatic Control of Thermal Conductivit Apparatus. E. M. Herrmann, R. B. Plat and W. P. Sinclair, U. S. Naval Enginee ing Experiment Station.

The paper describes flat plate and pip test conductivity apparatus used at th U. S. Naval Engineering Experiment Statio for determining the thermal conductivity various insulating materials. The apparatu previously manually controlled have bee modified for automatic operation. Use the automatic features eliminates constan surveillance by personnel with increase efficiency and yields more accurate and co sistent determinations.

Friday, June 30 2 p.m. Twenty-second Session

Held Simultaneously with the Twenty-first and Twenty-third Sessions

Corrosion of Ferrous and Non-ferrous Metals, Cast Iron, Water

Report of Committee A-3 on Cast Iron. J. S. Vanick, Chairman.

Report of Committee A-5 on Corrosion of Iron and Steel. T. R. Galloway Chairman.

Report of Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys. Jerome Strauss Chairman.

Report of Committee B-3 on Corrosion of Non-ferrous Metals and Alloys. K. G. Compton Chairman.

A Synthetic Sea Water and Its Corrosion Characteristics in Spray Testing. Thomas P. May, International Nickel Co., Inc., and A. L. Alexander, Naval Research Laboratory.

Generalizations about the chemistry of ocean water are used as a basis for comparing several existing formulas for synthetic solutions. These have served as substitutes for natural ocean water in certain laboratory test procesures. This comparison reveals faults in these formulas.

A new formula is proposed with exact reproduction of ion concentrations which are existent in natural ocean water above one part per million. Provision is made for adjustment of pH and for the addition of heavy metal ions when desired.

For characterizing the corrosive properties of this solution, salt spray tests have been conducted on a number of metals, using as spray solutions natural sea water, synthetic sea water, 3 and 20 per cent sodium chloride. The same metals have also be exposed in the atmosphere and in sea water at Kure Beach, North Carolina.

Spray Testing with Natural and Synthetic Sea Water. II. A Study of Organic Coatings. A. L. Alexander Naval Research Lab., and Thomas P. May, International Nickel Co., Inc.

As an extension of the work previously described using synthetic sea water as a medium for spray testing, a number of organic coatings were studied and their behavior noted when exposed to the spray of synthetic sea water, natural sea water, 3 and 20 per cent sodium chloride.

Typical organic coating systems were selected which find normal application to aluminum and magnesium in aircraft, steel surfaces in ships, and to metal components of mechanized equipment of a type used in the field. The data indicate that in general the results obtained from the use of synthetic and natural sea water agree rather closely; whereas the degradation resulting from the 3 per cent sodium chloride solution is, as would be expected, greater than that obtained from the 20 per cent sodium chlorid An excellent opportunity is presented f comparing the action of brine solutions wi natural and synthetic sea water, and th study appears more significant in view of th fair agreement between replicate test spec ments.

Report of Committee D-19 on Industri Water. Max Hecht, Chairman.

Jt. Research Committee on Boiler Feedwat Studies. W. C. Schroeder, Chairman.

Report of Committee B-5 on Copper ar Copper Alloys, Cast and Wrought. G. H Harnden, Chairman.

The Forming Characteristics of Berylliu Copper Strip. John T. Richards and El worth M. Smith, Beryllium Corp.

The results of tests to correlate the formi characteristics of beryllium copper strip wi usual specification properties including ul mate tensile strength, tensile elongation, a Erichsen cup test are reported. Form bility is expressed as the minimum sa radius for forming a 90-deg. bend by means a punch and die setup. The effects of te per, stock thickness, grain size, grain dire tion, and heat treatment upon formabili and miscellaneous design or specificati properties are noted.

Friday, June 30 2 p.m. Twenty-third Session

Held Simultaneously with the Twenty-first and Twenty-second Sessions

Petroleum Products, Fuels, Road Materials, Rubber

Report of Committee D-4 on Road and Paving Materials. F. H. Baumann, Chairman.

Report of Committee D-3 on Gaseous Fuels. A. W. Gauger, Chairman.

Report of Committee D-15 on Engine Antifreezes. H. R. Wolf, Chairman.

The Determination of Freezing Protection of Engine Antifreezes. R. E. Mallonee, National Carbon Research Labs., and F. L. Howard, National Bureau of Standards.

A simple apparatus and technique for the determination of the freezing protection of aqueous solutions of engine antifreezes based on the familiar cooling curve technique is described. The method was developed after extensive testing, by seven laboratories, of several proposed methods. Observations the cooperating laboratories on the limi tions of the apparatus are cited.

Report of Committee D-2 on Petrole Products and Lubricants. O. L. Ma Acting Chairman.

Report of Committee D-11 on Rubber Rubber-Like Materials. Simon Coll Chairman.

Late in May each member and committee member will receive a reservation form for the Annual Dinner and Luncheons. It should be returned promptly.

New Book of Standards Virtually Completed

All Six Parts of Widely Used Publication Now in the Mails

It is doubtful whether many members of the Society devote much of their valuable time in abstract thinking about the Book of A.S.T.M. Standards. They have probably been very busy with their own business activities and also with the task of developing in committees specific new standards or keeping old ones revised. However, there are some facts about the new 1949 Book of Standards which it is well to note, even if briefly.

For many weeks the various Parts, as noted below, of this Book have been going all over the world, not only those to members of the Society, but to those who purchase the many copies for use in production and use of the hosts of materials covered. Parts 3 and 6 of the book are now in the mails, Part 3 having been completed early in May, and shipment of Part 6 started about May 10.

There are many statistics about the book that we do not know—no one has told us how much it weighs, but the six parts constitute quite a load. There are not many publications that are issued in six parts, when you eliminate encyclopedias and books of that kind, and few books of this kind aggregate over 8000 pages—nor are there many books which can demand a price of $54 which we think is still a "buy" when one considers the thousands of manhours and hundreds of thousands of dollars which industry and government have invested in the preparation of these books).

All are glad that the job has finally been completed. The poor (?) printer can't get needled about every other day on where certain forms stand, and "how's the printing progressing," etc. Our people concerned with editing and publishing standards will utter a few sighs of relief (but not for long, because the 1950 committee reports are ringing out many new standards). The Treasurer who handles the distribution of the books may find his mail somewhat lighter since hundreds of the purchasing agents and other people are not hounding him on "Why haven't we received part x of the Book of Standards?," etc.

Thousands of the members and others who have been patiently waiting for the books can now refer to the standards reasonably quickly and get them in their latest approved form.

One might almost consider the Book of Standards as "Mr. A.S.T.M." It is the most widely distributed and unquestionably the most important of our numerous publications.

Facilities in Book:

Considerable effort is expended in making the Book as useful as possible. The distinctive backstraps help to locate it quickly in the bookcase or on the desk. A good quality cloth and substantial case and binding mean that the book will stand up under usage.

There is in each part a classified table of contents and there is also a second table of contents listing the specifications in order of serial designations. Then, each part of the book has a detailed subject index. With this combination the user should be able to find almost any specification quickly.

All of these physical attributes are important, but the most important thing is the authoritative nature of the contents. The publication might be bound in the best leather, printed on the most expensive coated stock, and be glorified in many ways, *but* what makes the publication of distinctive value would still not be altered. The fact that the specifications and tests included are competent, unbiased, widely applicable, and authoritative is the basic element for the utility and widespread use of the books. What makes these standards of such a high order of excellence is a combination of loyal cooperation and intensive effort by thousands of leading experts in many fields, working through committees that are headed by conscientious officers; the whole is focused through a time-tested procedure which insures that all interests concerned may have a voice. Neither the standards nor the books are perfect, but they represent the best judgments of men who are outstanding in their fields—men who understand that compromise is frequently essential, but who nevertheless are always striving to improve the quality of the thousands of materials covered in A.S.T.M. standards.

We, too, have little time for abstract thinking about the book, but this outstanding publication certainly provides plenty of food for thought.

1949 Books of A.S.T.M. Standards

Part 1—Ferrous Metals
Part 2—Non-Ferrous Metals
Part 3—Cementitious, Soils, Road and Waterproofing Materials
Part 4—Paint, Wood, Adhesives, Shipping Containers, Paper
Part 5—Fuels, Petroleum, Aromatic Hydrocarbons, Soap, Water, Textiles
Part 6—Electrical Insulation, Plastics, Rubber

List prices for Parts 1, 5, and 6, $10 each; Parts 2, 3, and 4, $8 each.
To A.S.T.M. members for extra copies: Parts 1, 5, and 6, $7.50 each; Parts 2, 3, and 4, $6 each. A complete set of all six Parts, $54; to A.S.T.M. Members, $40.50.
Members may procure on their membership any one Part without extra charge and additional parts at nominal annual charges shown on the annual dues statements.

New Symposiums and Compilations Available

THE completion of Parts 3 and 6 of the 1949 Book of Standards has allowed the simultaneous appearance of a number of compilations of standards which have been eagerly awaited by interested segments of the materials field. Some of these compilations recently released are on Cement; Mineral Aggregates, Concrete, and Nonbituminous Highway Materials; Glass; Electrical Insulating Materials; Plastics; and Rubber Products. Also off press during the past few weeks were the 1950 Appendix to A.S.T.M. Manual of Engine Test Methods for Rating Fuel, and two symposiums—Evaluation Tests for Stainless Steels and Accelerated Durability Tests of Bituminous Materials.

A new collection of data has also been published and represents a revision of Tables of Chemical Compositions, Physical and Mechanical Properties of Wrought Corrosion-Resisting and Heat-Resisting Chromium and Chromium-Nickel Steels. Brief reviews of some of these are offered below.

Symposium on Accelerated Durability Tests of Bituminous Materials:

IN AN earnest attempt to lay the foundation for the standardization of testing procedures and apparatus for bituminous materials by presenting accumulated data on related phases of durability and accelerated service tests, this symposium was sponsored by Committees D-4 on Road and Paving Materials and D-8 on Bituminous Waterproofing and Roofing Materials.

The 13 papers, introduction, and discussions of the papers describe the use and tests of asphalt, tar, and pitches for highway and roofing applications. The papers include:

- A Review of Accelerated Test Methods for the Evaluation of Road Tars—*E. O. Rhodes,*
- Characteristics of Carbon Arc Light Sources for Accelerated Exposure Testing—*W. W. Lozier,*
- Behavior of Bituminous Road Materials Under Accelerated Exposure Conditions and Laboratory Heat Tests—*Richard H. Lewis,*
- Accelerated Weathering of Road Tars—*E. W. McGovern,*
- Immersion-Compression Tests Compared with Laboratory Traffic Tests on Bituminous Concrete—*A. T. Goldbeck,*
- The Use of an Abrasion Test as a Measure of Durability of Bituminous Mixtures—*John H. Swanberg and W. L. Hindermann,*
- Test Methods for Performing Accelerated Durability Tests on Asphalts—*T. E. Stanton and F. N. Hveem,*
- Durability Tests—A Word of Caution—*G. L. Oliensis,*
- Accelerated Weathering of Pitches and Asphalts—*W. F. Fair, Jr., H. R. Beck, and B. K. McKee,*
- Mineral Stabilizers in Asphalt Roofing—*L. Kirschbraun, R. H. Cubberly, and F. W. Yeager,*
- A New Photographic Method for Evaluating Failure of Bituminous Materials Due to Weathering—*J. B. Hunter, F. C. Gzemski, and L. Laskaris,*
- The Design and Application of a Spark-Gap Instrument for Detecting Crack Failures of Asphalt Coatings During Weathering Tests—*A. H. Boenau and L. A. Baum*
- Experience with Radiation in Accelerated Durability Tests on Bituminous Materials—*Joseph Zapata.*

The 188-page Symposium (STP 94), 6 by 9 in., with heavy paper cover is $2 per copy; to A.S.T.M. members the price is $1.50.

Evaluation Tests for Stainless Steels—STP No. 93:

For workers in the field of stainless steel, there always has been a need for a laboratory testing technique that could be used to establish the effects of composition or heat treatment, or both, on the corrosion-resisting characteristics of stainless steels. On this basis, certain more or less standard corrosion-testing techniques have been devised and applied. Of necessity, these testing techniques have required the use of specific corrosive media under arbitrarily chosen testing conditions with respect to chemical concentration, temperature, duration of test, and the like. The most used of these testing methods have been the boiling nitric acid test as covered by A.S.T.M. Designation A 262 the so-called Strauss or acid copper sulfate test, and to a lesser extent, tests in mixtures of nitric and hydrofluoric acids.

This symposium, therefore, was arranged, presented, and published to provide a review of experience with these evaluation test methods and the relation of results secured with them to the performance of the stainless steels under actual conditions of use.

The papers and discussions in the symposium were presented at the 1949 Annual Meeting under the sponsorship of Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related A loys.

In the symposium are the followi papers and discussions:

- Present Knowledge of Low-Carbon 18–8 H. W. Gilbert
- Corrosion Resistance and Mechanic Properties of Low-Carbon Austenit Stainless Steels—D. C. Buck, J. Heger, F. J. Phillips, and B. R. Quenea
- Accelerated Corrosion Testing of Chr mium-Nickel Stainless Steel Wel ments—F. K. Bloom and M. E. Ca ruthers
- An Appraisal of Methods for Evaluati the Corrosion Resistance of Stainle Steels—M. H. Brown, W. B. DeLon and W. R. Myers
- Some Observations on Tests for Inte granular Susceptibility of 18–8 M Stainless Steels—Hilmer Ebling ar M. A. Scheil
- Influence of Carbon and Molybdenum the Intergranular Corrosion Resis ance of Austenitic Chromium-Nick Steels With and Without Columbium W. O. Binder and C. M. Brown
- Comparative Corrosion Resistance Stainless Steels in Various Acids—R. Mears, C. P. Larrabee, and C. J. Fetn
- Comparison of Plant Corrosion Test R sults on Austenitic Stainless Steels wit Results of Huey and Strauss Tests H. O. Teeple
- Results of Some Plant Corrosion Tes of Welded Stainless Steels—G. Comstock
- Testing Multiple Specimens of Stainle Steels in a Modified Boiling Nitric Ac Test Apparatus—W. B. de Long
- General Discussion

A multitude of tables, charts, curv are included as well as many excelle photomicrographs of various alloy stru tures useful in analyses and evaluati tests.

The symposium contains 200 pag and is $2.50. To members the price $1.85.

1950 Appendix to A.S.T.M. Manu of Engine Test Methods for Ratin Fuels:

THIS Appendix was pr pared by the Division on Combusti Characteristics of A.S.T.M. Committ D-2 on Petroleum Products and Lub cants. It includes changes (throu 1949) in the 1948 A.S.T.M. Manual Engine Test Methods for Rating Fue

The 1950 Appendix includes co plete information on installation a use of the Detonation Meter for t Motor Method and the Resear Method as optional equipment for t bouncing pin. It also includes revis statements regarding the reproducil ity of the five standard methods rating motor, aviation, and diesel engi

uels. Included also are revisions dopted in 1949 in the aviation method nd in Supplements II and IV.

The 1950 Appendix includes infor- nation on the use of a jacketed carbu- etor for rating experimental fuels of igh vapor pressure, which should prove f considerable interest to refiners using uels of this type in their blending opera- ions.

For convenience of the operators, a ummary table of the main equipment equired is included, as is also a list of ecommended torque values for use hen reassembling the test engines fter overhaul.

A list of equipment changes has been rought up to date and includes changes hrough 1949 so engine owners can etermine whether their test units are tandard and in accordance with latest pproved changes. The list covers the ajor changes adopted since 1940 which an be checked by visual inspection. list of errata and editorial changes in he 1948 Manual is also presented.

The 32-page Appendix is $1; the price o A.S.T.M. members is 75 cents.

-10 Tables:

A newly revised and published set of ata on the compositions and proper- es of the wrought corrosion-resistant nd heat-resistant chromium and chrom- um-nickel steels and alloy castings has een assembled by Subcommittee I on lassification of Data, of Committee A- 0 on Iron-Chromium, Iron-Chromium- ickel, and Related Alloys.

Data were collected and tabulated for ubcommittee I of Committee A-10 by ussell Franks of the Electro Metal- rgical Division, Union Carbide and arbon Corp.; J. W. Juppenlatz ebanon Steel Foundry; V. N. Krivo- ok and F. L. LaQue, International ickel Co., Inc., and E. A. Schoefer of he Alloy Casting Institute. The data ere edited by F. P. Peters of *Materials nd Methods*, Chairman of Subcommit- ee I.

The data represent (*a*) an interim evision of the "Tables of Chemical ompositions, Physical and Mechanical roperties of Wrought Corrosion-Re- sting and Heat-Resisting Chromium nd Chromium-Nickel Steels," pub- shed by the A.S.T.M. in 1942, plus (*b*) n entirely new section of data on cast on-chromium and iron-chromium- ickel alloys, not previously included in his publication. This is the first edi- on of these tables in which data for he cast alloys are presented along ith the wrought.

The present classification provides ata on those stainless steels that have eceived the widest commercial usage. he data have been divided into two parts—Part I on Wrought Alloys and Part II on Cast Alloys. Section A of Part I covers the wrought hardenable and nonhardenable ferritic straight chromium steels. The ferritic steels hardenable by heat treatment are indicated in the tables as martensitic and those not hardenable as simply ferritic. Section B of Part I covers the wrought austenitic chromium-nickel steels. Part II covers the cast alloy materials of these general compositional ranges. Section A covers the corrosion-resistant alloys and Section B the heat-resistant alloys.

The revision of the wrought steel data has been limited to bringing them up to date and to the inclusion of certain data on recently developed steels not presented in the previous edition.

The data for the different steels have been condensed to the simplest form to provide a ready reference for both the maker and user of the steels. As previously indicated, inspection has been made of a large amount of data, and those included herein provide the present representative information on the steels covered, as obtained from both producers and consumers. Single figures rather than ranges have been used to describe the several properties of these steels. These figures are representative values and not minimum or average values except where otherwise noted in the tables. The values in these tables should not be considered as specification figures as these may be found in the appropriate A.S.T.M. standards for this class of material as referred to in the tables.

While the classification of these data has been made under the jurisdiction of Subcommittee I of A.S.T.M. Committee A-10, it would have been impossible without the aid of the various groups that cooperated with this subcommittee, including the principal manufacturers and users of stainless steels, alloy castings, and alloying agents. Special thanks are due the Technical Committee on Stainless Steel of the American Iron and Steel Institute and the Specifications and Designations Committee of the Alloy Casting Institute for their close and helpful cooperation, and for the use of so many data provided directly by them, in the preparation of these tables.

The data are included in 80 pages, paper bound, and sell for $2.50. Member's price is $1.85.

Prices Reduced on Books

Occasionally the stock of some A.S.T.M. technical books which have been issued a few years back is such that it is desirable to conserve storage space and reduce inventory, and one method has been to offer some of these publications at considerably reduced prices. While the list of publications on which reduced prices have recently been established may seem an imposing one, it should be remembered that the Society issues a large number of books and reprints. The list prices of the books noted have been reduced from one third to one half, with corresponding reductions for members.

The publications noted here contain a wealth of authoritative technical information and data, much of it still up to date even though the books may have been issued some time ago.

One or more copies may be ordered at the special prices noted:

	List	*To Members*
1943 Symposium on Radiography	$2.50	$1.85
1944 Symposium on Plastics	$1.00	75 cents
1944 Symposium on Rubbers	$1.00	75 cents
1946 Books		
Statistical Quality Control	50 cents	25 cents
Atmospheric Exposure Tests on Non-Ferrous Metals	$1.00	75 cents
Oil Procurement Practices	50 cents	40 cents
1947 Books		
Testing Bearings	$1.00	75 cents
Testing of Parts and Assemblies	75 cents	60 cents
1947 Rubber Testing	$1.00	75 cents
1947 Synthetic Lubricants	50 cents	40 cents
Measurement of Entrained Air in Concrete	$1.00	75 cents
Forum on Diesel Fuel Oils	50 cents	40 cents
1948 Books		
Methods and Procedures Used in Identifying Reactive Materials in Concrete	$1.00	75 cents
Forum on Tractor Fuels	50 cents	40 cents
Functional Tests for Ball-Bearing Greases	$1.00	75 cents
Influence of Non-Ferrous Metals and Their Compounds on the Corrosion of Pressure Vessels	50 cents	40 cents

Editorial Error in Part 2, 1949 Book of Standards

In the Standard Specifications for Copper Silicon Alloy Rods, Bars, and Shapes (B 98 – 49) the title of Table II on page 99 of Part 2, 1949 Book of A.S.T.M. Standards should read "Tensile Requirements" and the last column of the table covering bend test requirements should be deleted.

The same correction should be made on page 99 of the December 1949 issue of "A.S.T.M. Standards on Copper and Copper Alloys."

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Important Examples of How Adequate Standard Tests Advance Research

——Standards Spearhead Development in Many Fields——

THE vital importance of standard specifications and test methods in the procurement and use of materials is apparent to almost everyone who produces or uses materials in any quantity. It is also apparent that the use of standards in procurement can be expanded and that there are numerous instances where adequate standards are not yet available. But there exists one broad area of application of standards which has been literally "hiding its light under a bushel." This is the very important application of standards in research and promotion of the many products that come from research.

To show how standards tie in with research, several case histories have appeared in recent ASTM BULLETINS. Fields of paint, petroleum, high temperature alloys, gaseous fuels, and others have been noted, the articles being based on communications sent by members of the Society to the Committee on Developmental Activities of the Board of Directors.

The case histories noted below in the trenchant style of Past President J. R. Townsend, relate to a variety of materials fields. It is logical that in writing on the subject, Mr. Townsend should note the application of standards and research over the whole materials field, because he was for many years Materials Standards Engineer and for some time has been Materials Engineer of Bell Telephone Laboratories, Inc. He has been active in numerous phases of A.S.T.M. work and on many of its technical committees. He has been chairman of Committee B-6 on Die-Cast Metals and Alloys for over fifteen years. He also represents the Society on the Standard Council of the American Standards Association.

This series of articles dealing with the significance of standards in research has been appearing under the auspices of the Developmental Committee of the Board of Directors. This committee was formerly headed by A. G. Ashcroft, and in his discussions with Mr. Townsend this important concept of the significance of standards in developmental work was first considered. Later discussions in the committee led to contacts with other members and eventually the whole problem of the Society's promotional activities was considered in the Board and has led to a new administrative committee now being organized to consider the broad problems of promoting the use of standards, the significance of the Society's work and other related matters.

A.S.T.M. Test Methods in Research

By John R. Townsend

ONE OF the best approaches to research is to devise and refine the methods and tools of measurement that may be involved. It is only to the extent that we are able to judge the value of innovations by significant measurement can we be assured of constructive forward progress. In the field of the development of methods of test and measurement and their cooperative acceptance by industry the A.S.T.M. has done outstanding service to engineering. I recall the following examples which illustrate the relationship between A.S.T.M. test method development and subsequent use of the test as an instrument of research.

Steam Chest Test:

It was early recognized that wet steam, 95 C., would accelerate phase changes and corrosion with die-casting alloys of zinc containing some aluminum. This test would produce results in about 96 hr. With the use of this test as an instrumentality, it was possible to develop die-casting alloys that would be stable and this resulted in the development of the Zamak alloys upon which the present zinc-base die-casting industry is based. The steam chest test continues to be used as a means of determining instability of alloys composed of metals widely separated in the electrochemical series.

A.S.T.M. Committee B-6 on Die Casting Metals and Alloys is the group in A.S.T.M. which fostered this important work involving die castings. The Specifications for Zinc-Base Alloy Die Castings, B 86, was first issued in 1931 and has been revised on several occasions since that time.

End Quench Test:

This test for hardenability of steel or "Jominy" test, was originally developed as an end point test to determine the suitability of steel for hardening. This was originally developed as a war measure and is now broadly used as an end point test to indicate the hardening characteristics of steel. In fact, this test has revolutionized the thinking with respect to hardening of steels, and it is to be expected, looking to the future, that chemical analysis may be of relatively little importance. This test is widely used as a research tool in the development of heat-treating methods and new alloys, and in studying the relationship between hardenability, section size, and such properties as impact resistance, ductility, notch-bar sensitivity, and endurance limits.

A good many organizations are using the end quench hardenability bands to procure steel. The A.S.T.M. test on which limits are based is A 255, under the jurisdiction of A.S.T.M. Committee A-1 on Steel. To permit plotting hardenability curves, a standard chart was developed for use with the test.

Salt Spray Test for Electrodeposited Coatings:

This test was originally developed to determine the suitability of zinc coatings in service. It is now widely used as a research tool for the selecti

f coating processes, design of anodes, nd for correlation testing with service xperience. Results of this test have argely revolutionized thinking with espect to electroplating methods and ave resulted in more efficient use of lating. This test has also aided the evelopment of automatic plating.

The A.S.T.M. Tentative Method of alt Spray (Fog) Testing (B 117) was ssued some ten years ago and the latest evision incorporated in 1949. This ethod has also been approved by the merican Electroplaters Society.

'ore Loss Test:

In the field of magnetic materials, the ore loss test has been widely used to mprove the quality of magnetic iron rocessing methods with respect to olling sheet and has advanced the tudy of scale and scale adherence.

This test is found in A.S.T.M. Meth-ds A 343–49, Alternating Current Core oss and Permeability of Magnetic Iaterials, which is used in conjunction ith the general Methods of Testing f Magnetic Materials, A 34.

C-ray Diffraction Identification of Crystalline Materials:

This test, by the Hanawalt method n A.S.T.M., the Recommended Prac-ce E 43) is widely used as a research tool in the study of alloys. Quoting directly from E 43, it "is advantageous for the analysis of unknown materials in that it gives the state of chemical combination of the elements present, requires only minute test specimens and, in general, does not require great accuracy of measurement." Data for the identification of about 4200 compounds for use with this recommended practice have been compiled in a Card Index File, now being issued in revised form.

Rockwell and Superficial Hardness Tests:

The Methods of Test for Rockwell Hardness and Superficial Hardness of Metallic Materials found in A.S.T.M. Method E 18 are basic to control of heat treatment, alloy composition of both ferrous and non-ferrous metals, and are widely used in research and development. They are also used in the diagnosis of troubles occurring in the field.

Magnetic Particle Testing of Metallic Parts:

The magnetic particle testing of metallic parts to show tears, cracks, inclusions, shrinkage, and blowholes is almost too widely known to be mentioned. Nevertheless, it is a most useful tool in metallurgical research and inspection of castings. After all, each casting is a universe unto itself and the magnetic particle testing is a very widely used adjunct to X-ray inspection.

The A.S.T.M. Methods of Magnetic Particle Testing and Inspection of Heavy Steel Forgings, and of commercial steel castings, A 275 and A 272, respectively, were issued during the last war so that there would be standardized procedures and techniques for carrying out the tests.

Mercurous Nitrate Test for Copper and Copper Alloys:

This test (A.S.T.M. Method B 154) is widely used to detect susceptibility to season cracking. This method is a specific requirement for condenser tubes, and for wrought brass, bronze castings, and the like and is widely used in metallurgical studies.

Tests for Electrical Resistance Alloys:

There is a whole series of tests for electrical resistance alloys: namely, resistivity, A.S.T.M. Method B 63; thermoelectric power, B 77; and temperature resistance constants, B 114 and B 84. These tests are basic to the whole field of resistance alloys and are widely used as engineering tests and research studies of alloys.

Low Temperature Testing of Plastics:

The aging of plastics is indicated by a rise in the low-temperature brittleness value. This fact is the basis of one of the most widely used tests for the study of deterioration of organic materials and their suitability for low-temperature use. The value can be determined by A.S.T.M. Method D 746, Test for Brittle Temperature of Plastics and Elastomers.

Although not by any means an exhaustive list, this covers a few cases that come to mind. I am certain that it would be easily possible to go through the A.S.T.M. standards and check off a great number of test methods which are widely used and frequently are essential in research work. I think you have placed your finger on an area of A.S.-T.M. work that is in need of as much publicity as can be given it.

Important Note on Copper Requirement in Flange and Firebox Steel Plate Specification

TENTATIVE Specifications A 285 – 49 T for Low and Intermediate Tensile Strength Carbon Steel Plates of Flange and Firebox Qualities as printed in Part 1 of the 1949 Book of Standards and in the special compilation "A.S.T.M. Specifications for Steel Flat Products" soon to be issued contains an important editorial error in Table I on Chemical Requirements.

The maximum copper content requirement of 0.35 per cent for all grades of both flange and firebox quality plates should be deleted from Table I. In its place a Footnote *b*, referenced after the table title, should be added below the table to read:

> "[b] Steel plate furnished to these specifications may be ordered in copper steel; when so ordered the copper content in such plate shall not exceed 0.35 per cent on ladle analysis."

S. E. Fitterer New Member of A.S.T.M. Headquarters Staff

SHELDON E. FITTERER has recently joined the Headquarters Staff in Philadelphia, reporting to the Society's Technical Secretary. He will be concerned primarily with editorial work of a broad nature, but involving especially standards, reports, and committee publications.

After attending Rutgers University, he was employed with E. I. du Pont de Nemours & Co., and then was technical writer with the U. S. Signal Corps, War Department. Subsequently he became Supervisory Editor with the General Electric Co. in Schenectady. Later he was Assistant to the Advertising Manager of Thomas A. Edison, Inc., and then returned to the du Pont organization.

His work at Rutgers has been supplemented by courses at Temple University and also company-sponsored courses. A native of New Jersey, he is at present residing in Newcastle, Del.

Including Mr. Fitterer, the Society staff at Headquarters now totals 54.

Pacific Coast Technical Papers

Several of the papers presented at the First Pacific Area Meeting of A.S.T.M., last fall, have already been published (January, February, and April, 1950, ASTM BULLETINS). Many more will appear in forthcoming issues or in other Society publications. A few are appearing in *Western Construction News* and *Foundry* as was announced in the April BULLETIN.

A complete list of the papers presented at the Pacific Area Meeting appears in the current volume of *Proceedings* (1949) with an indication of the form and place in which each will be published.

Use of A.S.T.M. Radiographic Standards

THE accompanying photograph shows the use of the A.S.T.M. Industrial Radiographic Standards for Steel Castings which the Society published and which have been rather widely distributed among leading steel casting producers and users. The purpose of these standards is to aid in classifying defects revealed in castings subjected to radiographic inspection. In the picture the gammagraph at the left is being compared with the A.S.T.M. film by LeRoy Fink, Metallurgical Technician and James T. Gow, Chief Metallurgist, Electric Steel Foundry, Portland, Ore. This active organization, a Company Member of A.S.T.M., makes entensive use of the A.S.T.M. Standards. This illustration was part of an article in the company's house organ, *The ESCO Ladle*, which described the part which gamma radiography plays in steel casting production. It is of interest to note that Mr. Gow did early pioneering work in the use of gamma radiography when he was at the U. S. Naval Research Bureau in the 1920's.

DISTRICT ACTIVITIES

SEVERAL interesting recent meetings have been held under the auspices of the A.S.T.M. Districts in St. Louis, Chicago, New England, and Western New York-Ontario. Short news accounts of the St. Louis and Chicago meetings appeared in the April BULLETIN. No attempt is made in the few notes that follow to detail the meetings, but rather to give a general account. In each case the meetings were well attended.

New England, April 10—Competitive Sources of Energy:

There were about 100 members and visitors at the New England meeting at Northeastern University in Boston on April 10. Warren K. Lewis, Professor Emeritus of Chemical Engineering, Massachusetts Institute of Technology, discussed Competitive Sources of Energy. One of the pioneering leaders in the development of the new concept of chemical engineering, Dr. Lewis, who recently received the New England Award for 1950 presented by the Engineering Societies of New England, discussed the relationship of such fuels as coal, petroleum, gas, electrical energy and others. The interrelation of some of these fuels was noted and reference made to some of the possibilities now being explored, such as the use of oil shales. Dr. Lewis spoke in his usual interesting informal fashion. At the close there was considerable discussion on the responsibilities of the engineer and scientist in insuring that our fuel sources are used to best advantage.

Western New York-Ontario, April 21—Functional Photography:

Some details of this meeting were noted in the April BULLETIN. About 75 members of the A.S.T.M. and the Engineering Institute of Canada attended the dinner and technical session which featured a talk by George Eat of the Eastman Kodak Co., in conne tion with the Eastman film, "Function Photography." O. W. Ellis, Chairma of the A.S.T.M. Western New Yor Ontario District, and A. G. Aspli Chairman of the Niagara Peninsu Branch of the E.I.C., presided jointly the meeting. A.S.T.M. President J Morrow came over to St. Catharin from Hamilton and spoke briefly, e pressing his appreciation of the privile of being President of the Society a reasserted that great honor had be accorded Canada by his election.

During the afternoon, members both organizations enjoyed plant visi to the Decew Falls power station of t Hydro-Electric Power Commission Ontario, and the Thorold plant of t Ontario Paper Co.

This is the second of two excelle meetings which have been sponso recently by the local sections of t E.I.C. and A.S.T.M.

Western and Southern Members Meet in Various Centers

Groups in Los Angeles and San Francisco Convene; Initial Meetings in Twin Cities, Portland, Dallas, Houston, New Orleans

A.S.T.M. Members in several western and southern industrial centers met together for the first time during a visit in March to the West Coast by Assistant Secretary R. J. Painter. It had been planned that a member of the staff would visit San Francisco and Los Angeles, meeting with our district councils there, to continue a development of the increased A.S.T.M. activities which were stimulated by the very successful First Pacific Area National Meeting in San Francisco in October. On the way to the Coast the Assistant Secretary attended a dinner meeting of the members in Minneapolis-St. Paul, and in Portland, Ore., and following the Los Angeles district meeting, briefly described below, visits were made to Dallas, Houston, and New Orleans where luncheon meetings of the members were held.

During the past ten years or so, the membership has increased considerably in many Western and Southwestern industrial areas, and although it is not anticipated that any new A.S.T.M. districts will be organized, it was felt to be advantageous from several standpoints, to have our members get together, meet each other, and discuss any pertinent A.S.T.M. activities which would be especially significant from the standpoint of the respective areas.

A similar pattern prevailed for the meetings except for the Pacific Coast cities. Following an assembly period when our members met each other, there was a short illustrated talk by the Assistant Secretary, followed by a general discussion. Members who cooperated closely in arranging the luncheons or dinners, included the following:

Twin Cities: Fred G. Wehmer, Minnesota Mining & Mfg. Co., H. G. Burnham, Northern Pacific Railway Co. and J. H. Swanberg, Minnesota Highway Dept.

Portland: T. K. May, West Coast Lumbermen's Assn., H. H. Richmond, Electric Steel Foundry Co., and S. H. Graf, Oregon State College.

San Francisco: T. Parker Dresser, Abbot A. Hanks, Inc., Dozier Finley, Research Consultant, Paraffine Cos., and Paul V. Garin, Southern Pacific Co.

Los Angeles: Claude E. Emmons, The Texas Company, Fred J. Converse, Calif. Institute of Technology, and H. W. Jewell, Pacific Clay Products.

Dallas: Edwin Joyce, American Petroleum Institute, J. M. Frankland, Chance Vought Aircraft Div., United Aircraft Corp., and E. F. Schmidt, Lone Star Gas Co.

Houston: A. C. Speer, Johns-Manville Corp., and C. S. Wilson, Texas & New Orleans Railroad Co., and Roy E. Hall, Wyatt Metal and Boiler Works.

New Orleans: Cecil E. Shilstone, Shilstone Testing Laboratory.

In Portland, Prof. S. H. Graf, Director, Engineering Experiment Station, Oregon State College, discussed the development of the testing of materials and products and described some of the early formitive years of A.S.T.M. He had with him a copy of the Society's first volume of *Proceedings* from which he quoted and mentioned the names of many of those who pioneered in A.S.T.M. activities, including Howe, Merriman, Marburg, Dudley, and many others. He praised the work of A.S.T.M. and expressed the hope that a Society group might be organized in this area. With Professor Graf at the meeting were a number of other A.S.T.M. members and his associates from Oregon State College.

The meeting in San Francisco was confined to the District Council which discussed several items of business. This group, together with members from the Southern California Council, was the nucleus of the Arrangements Committee which "spark-plugged" the October National Meeting. Reference is made elsewhere to a number of publications resulting from this meeting.

Society Activities:

Some of the chief purposes of this trip were to stimulate membership and to impress on our members in these centers, the desirability of participation in technical committee activities where this is feasible. Although distance sometimes is an obstacle for active participation in committee work, yet many important developments are taking place and our members there should take part in the considerations involving standards and research.

Southern California Meeting

Coinciding with the visit to Los Angeles of the Assistant Secretary, the Southern California District held a meeting on Thursday, March 23, at the Rodger Young Auditorium. The program was designed specifically for the A.S.T.M. membership and, deviating somewhat from the district's customary procedure, invitations were not extended to members of other sections and chapters, although anyone interested was welcome.

Following dinner, the program proceeded as follows:

Illustrated Talk on A.S.T.M.—R. J. Painter, Assistant Secretary

A.S.T.M. Committee Activities Brought Up to Date

Petroleum—George Lake, Research Supervisor, Union Oil Co.

Rubber—R. B. Stringfield, Consulting Chemical Engineer

Ceramics—Norman Kelch, Technical Director, Brick Manufacturers Assn. of So. Calif.

Plastics—John Delmonte, Technical Director, Plastics Inst.

Ferrous Materials—E. O. Bergman,

Dinner Meeting in Portland: From l. to r.: H. H. Richmond, Electric Steel Foundry Co.; Prof. S. H. Graf, Oregon State College; T. K. May, West Coast Lumbermen's Assn.; and R. J. Painter, Assistant Secretary, A.S.T.M.

Technical Adviser, C. F. Braun and Co.
Non-Ferrous Materials—Frank Bolte, Assistant Chief Engineer, North American Aviation

Several of the talks were based on latest developments from committee meetings held either during A.S.T.M. Committee Week, or in the first quarter of the year. Mr. Bolte stressed emphatically, the need for tests which will give us a better evaluation of the properties of materials as used in airplane structure or in other places where the designer wishes to make use of maximum properties of a material. He felt that in the fields which provide the bulk of materials used in the aircraft industry, more work needs to be done to get authoritative information on properties which are not evaluated in some of the more common static tests. (In this connection, members are referred to a paper in the May BULLETIN covering Fatigue Characteristics of Aircraft Materials and Fastenings, by Messrs. Piper, Finlay, and Binsacca of Northrop Aircraft, Inc.

Those present gained an excellent concept of the great amount of work under way in the materials fields discussed at the meeting.

The District officers, C. E. Emmons, The Texas Co., *Chairman;* F. J. Converse, California Institute of Technology *Vice-Chairman;* and H. W. Jewell, Pacific Clay Products, *Secretary*, handled the details of the meeting and dinner. Claude Emmons presided in his usual interesting fashion.

Notes by the Assistant Secretary

It is obviously difficult to write in a few words one's reaction to an extensive trip, after meeting dozens of our members for the first time, and making contacts with many organizations and individuals interested in A.S.T.M. But some thoughts might be noted.

It is a continuing inspiration to realize what a genuine interest in the Society is taken by so many of our busy members. It seems that no group could have a more helpful, cooperative membership. Most of our men have their professional groups, and a large number take an active part in civic affairs and related work, yet they have a keen appreciation of the significance of A.S.T.M., and practice what is often preached, that an organization like our Society is but a reflection of the members' own work in it. All of us on the Staff have found our members, whether in the West, South, North, or East, the kind we would expect...and with whom we are anxious to cooperate.

Interest in our publications was everywhere evident. How many times I was asked, "How are the Books of Standards coming along?"

Closer participation in our technical activities on the part of our members in the Southwest, West Coast, and Northwest is desirable—attendance at meetings obviously cannot be the regular practice it is for those East of the Mississippi—but the viewpoint of our people in the West is essential.

For one who is concerned with membership promotion and developmental activities, there were suggestions and opportunities at every turn. So that maximum benefits shall come from our extensive research and standards work, more companies and government workers must know about A.S.T.M. and use its standards when feasible. There is much plowing to be done and a whole lot of territory we haven't dug into yet. R. J. P.

TECHNICAL COMMITTEE NOTES

Committee on Wax Polishes and Related Materials Organizes

A NEW field of ultimate consumer goods had been entered by the Society through the organization of a technical committee on wax polishes and related materials. The last issue of the BULLETIN gave some of the background leading up to the organization of this committee and referred to some of the important standardization problems which it will propose to solve.

The organization meeting of Committee D-21 on Wax Polishes and Related Materials was held at A.S.T.M. Headquarters on April 14, 1950. All those present had the opportunity to offer comments and suggestions on their particular interests and on what they considered to be the needs in standardization of materials in the floor wax industry. It was evident that although specifications are desired the initial efforts of the committee should be directed toward standardizing test methods and nomenclature. In developing test methods, performance tests were stressed as well as the determination of physical properties. In so far as the particular types of products are concerned, water-emulsion type waxes will probably receive first consideration in the development of test methods. Automobile, furniture, and other type waxes will be included later in the work of the committee.

A proposed scope for the committee was accepted by the newly appointed Executive Subcommittee to read as follows:

> The stimulation of research, and the formulation of test methods, definitions of terms, and specifications, of wax polishes and related materials, including the materials entering into their manufacture.

In addition to the Executive Subcommittee, five other subcommittees were designated with chairmen selected as noted.

Subcommittee I on Nomenclature (D. B. Hanley)
Subcommittee II on Raw Materials (M. Fuld)
Subcommittee III on Chemical and Physical Test Methods (D. M. King)
Subcommittee IV on Performance Tests (M. Sveda)
Subcommittee V on Specifications (W. H. Joy)

The next meeting of the committee is planned for September 14 and 15 to be held at the National Bureau of Standards, Washington, D. C. The present personnel of the committee are as follows:

Temporary Chairman: J. I. HOFFMAN, National Bureau of Standards, Washington 25, D. C.

Temporary Vice-Chairman: J. V. STEINLE, S. C. Johnson Co., Racine, Wis.

Temporary Secretary: B. S. JOHNSON Franklin Research Co., Philadelphia, Pa

Consumers

Asphalt Tile Institute, C. B. Whittlesey Jr.
Bell Telephone Co., W. H. Joy
Educational & Institutional Coop. Service Inc., L. F. Robbins
Hood Rubber Co., R. E. McCurdy
Johns-Manville Inc., E. H. Berger
Montgomery Ward Co., L. M. Schilb
National Inst. Governmental Purchasing Albert Hall
Public Housing Adm., R. Skagerberg
Rubber Mfrs. Assn., C. P. McFadden
Specifications Branch Standards Division Federal Supply Service GSA, D. B Hanley

Producers

Armstrong Cork Co., A. Lefevre
A. Bowers, Hunt Mfg. Co.
Boyle-Midway, Inc., J. T. Hohnstine
Congoleum-Nairn, Inc., D. H. Spitzli
Fuld Bros., Melvin Fuld
C. B. Dolge Co., Clarence L. Weirich
Franklin Research Co., B. S. Johnson
R. M. Hollingshead Co., Victor M. Mant
S. C. Johnson Co., J. Vernon Steinle
Masury-Young Co., D. M. King
Simoniz Co., P. E. Wenaas
A. T. Sodergreen, West Disinfecting Co.
R. B. Trusler, Davies-Young Soap Co.
Vestal, Inc., M. Martin Maglio

General Interest

American Wax Importers and Refiners Assn., Andrew Bohart
Cornelius Products Co., Fred W. Rau

Durez Plastics & Chem. Inc., Herbert J. Mellan
E. I. du Pont Co., Grasselli Chemicals Dept., M. Sveda
Henry A. Gardner Laboratory, R. S. Hunter
Liberty Mutual Life Ins. Co., Stuart W. Gurney
Metropolitan Insurance Co., L. S. Reid
Nat. Bureau Standards, W. W. Walton, P. Sigler
Petrolite Corp. Ltd., A. W. Marshall
Foster D. Snell, Inc., C. S. Kimball
Travelers Insurance Co., Reuel C. Stratton
Underwriters' Laboratories Inc., Sydney V. James
U. S. Testing Co., T. Smith Taylor

Absorption Spectroscopy Committee Holds Organization Meeting

In view of the expanding interest and activity in absorption spectroscopy, a new A.S.T.M. Committee—E-13 on Absorption Spectroscopy—has been organized, the organization meeting being held February 15, in Pittsburgh, in connection with the Pittsburgh Conference on Applied Spectroscopy. Until recently absorption spectroscopy has been included within the scope of A.S.T.M. Committee E-2 on Spectrographic Analysis. However, that committee has devoted its attentions almost entirely to the field of emission spectroscopy, and the importance that absorption spectroscopy is now assuming in industry would indicate that greater attention should be paid to this field in A.S.T.M. Research and analytical methods are being employed in the infrared and ultraviolet ranges, as well as in the visual range. There has also been considerable activity in assembling reference curves for various compounds, particularly hydrocarbons, in the infrared and ultraviolet ranges. Committee E-2, after giving considerable study to the subject, accordingly recommended that a separate committee on absorption spectroscopy be set up, leaving to Committee E-2 the field of emission spectroscopy.

In line with this recommendation the Board of Directors authorized the organization of the new Technical Committee on Absorption Spectroscopy, resulting in the organization meeting referred to above. The proposed scope for the operation of the committee is as follows:

> "The coordination and formulation of methods of spectroscopic analysis by absorption, fluorescence, and scattering techniques."

It is expected that the work of the committee will consist largely in coordinating the work of other A.S.T.M. technical committees on methods involving any of the above techniques. The committee will also be responsible for the initiation of work of general interest in its field, as for example, on instrumentation, definitions, reference curves, etc.

At the organization meeting, the Temporary Chairman, Dr. Wallace R. Brode, Associate Director of the National Bureau of Standards, was elected the Permanent Chairman, E. J. Rosenbaum, Sun Oil Co., Vice-Chairman. A steering committee was appointed to complete the organization of the committee.

Committee D-13 on Textile Materials

The Spring Meeting of Committee D-13 on Textile Materials held in New York, N. Y., on March 15 to 17, was featured by the first award of the Harold DeWitt Smith Memorial Medal, a testimonial luncheon to retiring Chairman Ball, and a symposium on shrink proofing of textiles. The medal award to Dr. H. F. Schiefer was announced in the April ASTM Bulletin. The tribute to Professor Ball is described below.

H. J. Ball Honored:

As a testimonial of the esteem of his associates and many friends in Committee D-13, Professor Ball was presented with an appropriate scroll (see photograph) and a sum of money to purchase a combination radio and phonograph. The presentation was made by Dr. Frederic Bonnet, American Viscose Corp. The scroll, in recognition of 20 years service reads in part as follows:

> *"His valued contribution to the development of standards and test methods in the textile industry;*
>
> *"His vision and courage in guiding that committee in the progressive growth to its present high standing and position of prestige in the industry;*
>
> *"His integrity and sincerity, which has inspired all who have worked with him . . ."*

Preceding the presentation of the scroll, Giles E. Hopkins, Technical Director of the Wool Bureau, addressed the luncheon gathering recalling some of the outstanding services rendered by Prof. Ball to Committee D-13 and to the Society.

Prof. Ball's services during these years were not confined to Committee D-13 as he held many offices in the Society, including the following:

American representative to the International Standards Association—1938 to its reorganization as International Standards Organization.
Representative on the American Standards Association Advisory Committee

Textile World

Professor Ball (center, right) retiring Chairman of Committee D-13, receiving a scroll in recognition of his twenty years of service as Chairman, from Frederic Bonnet (center, left), Vice-Chairman, while W. H. Whitcomb (left), Toastmaster and Chairman of the Testimonial Dinner, and Giles E. Hopkins (right), Technical Director, the Wool Bureau, look on.

on Ultimate Consumer Goods—1940 and 1943.
Chairman, A.S.T.M. Administrative Committee on Ultimate Consumer Goods—1945 to present.
Member, A.S.T.M., New England District Council—1946 to present.
Member of the A.S.T.M. Board of Directors—1934 to 1936, 1939–1940.
Vice-President, A.S.T.M.—1940 to 1942.
President, A.S.T.M.—1942 to 1943.
Delegate to International Standards Organization meeting at Buxton, England—1948.

Following the policy of Committee D-13 to have prominent technologists discuss timely subjects at each of its meetings, a Symposium on the Dimensional Stability and Shrink Proofing of Textiles was held on Thursday, March 16, at 2 p.m., at which the following three papers were presented:

"The Dimensional Stability and Shrink Proofing of Cottons," by E. C. Pfeffer, Cluett Peabody, Troy, N. Y.
"The Dimensional Stability and Shrink Proofing of Woolens," by W. von Bergen and Claude Clutz, Forstmann Woolen Co., Passaic, N. J.
"The Dimensional Stability and Shrink Proofing of Rayons," by J. A. Woodruff, American Viscose Corp., Marcus Hook, Pa.

It is expected that these three papers will appear in the July issue of the ASTM Bulletin.

At this meeting there were sessions of 20 subcommittees and sections. The projects assigned to a number of recently organized task groups were advanced by sessions held during the meeting. The committee decided to organize a new Subcommittee A-7 on Ultimate Consumer Textile Products which will take over the work of the present Subcommittees A-6 on Household and Garment Fabrics and A-12 on Hosiery. The present members of these two latter subcommittees will constitute for the present the members of the new subcommittee. The immediate attention of this committee will be devoted to a consideration of test methods for consumer products where there is an indicated need for them.

Complete test procedures for rayon yarns and threads are in preparation. These will constitute a consolidation of the present tests in Methods D 258 and D 507 but will also include information on significance of the tests covered and the establishment of conformance with specifications. It is expected that the methods will be completed by the October, 1950, meeting. The tolerances for rayon yarns and threads now appearing in Methods D 258 and D 507 will later be combined and issued as a separate standard.

The method for determination of vegetable matter in scoured wool now published as information was revised and will be issued as tentative. Plans were completed for a study of a new method for tensile strength of wool by about 10 cooperating laboratories. Samples of wool will be supplied by the Textile Research Institute wool project. A study of moisture in wool by inter-laboratory cooperative tests using the distillation technique may be undertaken in the near future. The results of the latest inter-laboratory studies of tests for fineness of wool were reviewed, based on methods D 417 and D 472. The data showed little difference between the short fiber and long fiber methods. The study included a review of the variables of past laboratory tests *versus* those of recent tests. The latest tests showed better control from laboratory to laboratory. The greatest source of variable was between operators. This study will be continued. Terms and definitions relating to wool were also considered.

The Subcommittee on Asbestos Products completed revisions in the Specifications for Asbestos Yarns (D 299 – 49 T) and for Asbestos Roving (D 375 – 49). It recommended adoption as standard of the Tentative Specifications for Woven Asbestos Cloth (D 677 – 46 T). Revisions in the Specifications for Asbestos Lap (D 1061 – 49 T) are under consideration.

The Subcommittee on Bast and Leaf Fibers reviewed further results from the round-robin on twine testing being made in some nine cooperating laboratories. A "Monograph on Uniformity in Jute Fiber" was presented by O. P. Beckwith at the subcommittee meeting.

The Subcommittee on Glass Fiber and Its Products discussed at its meeting test for spread and build-up of glass yarns, diameter measurements of glass cords, color fastness of dyed glass fabrics, and abrasion of glass fabrics.

A combined set of testing procedures for cotton and rayon tire cords representing a consolidation of Methods D 179 and D 885 was reviewed by the Subcommittee on Tire Cord and Fabrics. While agreement has been reached on a large number of the individual test procedures, further consideration is to be given to certain features of the methods. It is hoped to complete the new draft by the October meeting.

While the Felt Subcommittee did not meet, it was reported that specifications for mechanical sheet felt had been completed and would be issued as tentative this year. Task Groups to study stiffness tests and the thickness measurements of cut parts have been appointed.

The Subcommittee on Carpets presented new tentative methods for resistance of pile floor covering to insect pests. This subcommittee is studying flame resistance tests, wear testing, ravel resistance, evaluation of hand of carpets, and light fastness test.

The first set of testing procedures for bonded fabrics were completed and will be issued as tentative this year. These tests are applicable to fabrics which are built up by the interlocking of fibers resulting from one or a combination of the following: a chemical bonding material, mechanical action, chemical action, and moisture and heat. The methods include test procedures for bursting strength, breaking strength by the grab and cut strip methods, and weight. Other methods for bonded fabrics under study include review of existing instruments for air permeability, water absorbency, tear resistance, laundering, dry cleaning, fire retardancy, abrasion resistance, and flexural rigidity.

A session held on Thursday, March 16, was devoted to the work of the Subcommittee on Methods of Testing at which reports were received from some twelve active task groups and was concluded by a papers session. A further session of the Task Group on Abrasion Testing was held on Friday, March 17. A new set of methods for resistance of textile fabrics to water were accepted as tentative to replace the present Methods D 583. The revised methods include procedures for determining resistance of textile fabrics to: (1) external (surface) wetting, (2) internal wetting (absorption), and (3) penetration by water. They are applicable to all fabrics, both treated and untreated, regardless of fiber compositions. The three procedures are known as the spray test, dynamic test, and the AATCC rain test.

Revisions were submitted in the Tentative Method of Test for Fastness of Colored Textiles to Light (D 506 – 45 T) and also in the procedures for determining copper, manganese, and nickel in textiles (Methods D 377 – 47 T). Following study by a task group of four methods for the quantitative analysis of mixtures containing nylon it was decided to revise Methods D 629 by inclusion of the hydrochloric acid method which was found to be the most satisfactory.

The Task Group on Antiseptic Finishes presented proposed specifications for shower curtains and also revised methods of test for resistance of textile materials to microorganisms. These methods represent a revision of Method

684 and cover the accelerated mildew fection method which is applicable to xtile materials (including textile overed objects such as instrument ases and electrical wires) that are exected to be used or stored in a damp, arm atmosphere, but out of contact ith damp soil; and the soil burial ethod which is applicable to textile aterials that are expected to be in conct with damp soil for long periods of me, such as sandbag fabrics stored on amp ground.

Interesting progress reports were presented from the other task groups on nitted fabrics, field test for performnce in use, evenness in yarns, elastic brics, stress-strain curves, identification of finishes of textiles, quantitative ethod of separating cotton from viscose rayon, fluidity test, and fire-resistnce methods.

The Papers Session held at the conclusion of the subcommittee meeting was evoted to the following three papers iscussing methods of evaluation of hand f fabrics:

"A Fabric Internal Friction Test for Evaluation of Textile Softening and Stiffening Agents," by D. D. Gagliardi, Rohm & Haas Co., Philadelphia, Pa.

"New Methods for Drape Characteristics," by Walter Hamburger, Fabric Research Laboratories, Boston, Mass.

"F. T. Peirce's Methods," by Lyman E. Fourt, Harris Research Labs., Washington, D. C.

Committee D-9 on Electrical Insulating Materials

A NUMBER of new and revised standards were completed by Committee D-9 on Electrical Insulating Materials at its three-day spring meeting held at the Chamberlin Hotel, Old Point Comfort, Va., on March 20 to 22. Preceding the meeting of the main committee, there were meetings of 25 working subcommittees and sections with an attendance of over 125 members and guests. All of the actions taken at this meeting are subject to approval by committee letter ballot before presentation to the Society in June at the Annual Meeting.

Revisions were completed in the Tentative Specifications for Orange Shellac and Other Indian Lacs for Electrical Insulation (D 784 – 44 T) and in the Methods for Testing Shellac (D 411 – 44). Work is under way on development of methods for silicone insulating varnishes, and studies are being made of tests for set time of laminating varnishes and for oil resistance.

New specifications for cellulose acetate sheet and film were presented for publication as tentative. In preparation are specifications for electrical grades of polyethylene and polystyrene in the form of sheets, tapes, and films. A stress relief test was accepted for inclusion in the Methods of Testing Nonrigid Polyvinyl Tubing (D 876 – 46 T). A bursting strength test for laminated tubes is under development and revisions in the specifications for laminated thermosetting materials to cover nine grades of laminates are in preparation so that the A.S.T.M. Specifications D 709 will be in substantial agreement with the JAN and NEMA specifications.

The Tentative Methods of Testing Electrical Insulating Oils (D 117 – 49 T) were further revised and rearranged to include approved definitions and significant statements for the various tests. Principal additions cover the power factor and interfacial tension tests. These methods apply to mineral oil of petroleum origin for use in cables, transformers, oil circuit breakers, and other electrical apparatus as an insulating or cooling medium, or both. The following four test procedures for inhibited transformer oils are under study: (1) modified sludge accumulation test (2) modified turbine oil stability test (3) modified (bomb) pressure test (4) oxygen absorption test.

Consideration is being given to a new design of a power factor and resistivity cell used for routine testing of cable oils. Revisions were accepted in the Methods of Testing Askarels (D 901 – 49 T).

Excellent progress was reported in the studies of test methods for microcrystalline waxes. Based on cooperative test data, methods are now being prepared for volume contraction and expansion characteristics, and cold flow point. Studies are being made of a brittleness test and a falling-ball test.

Revisions in the Tentative Specifications for Varnished Cloth Tapes (D 733) have been approved and also in the Methods of Testing Varnished Cloths and Varnished Cloth Tapes Used in Electrical Insulation (D 295 – 49 T). A new method for insulation resistance of varnished cloth is under study as is also a new procedure for determining resistance to heat aging of treated glass fabrics.

Revisions in the Methods of Sampling and Testing Untreated Paper Used in Electrical Insulation (D 202 – 49 T) have been approved by letter ballot of Committee D-9. The revisions will add new test procedures for determining water-soluble matter, alcohol-soluble matter, and water-soluble sulfates; also definitions and significance statements on tests for thickness, bursting strength, folding endurance, air resistance, and impregnation time. Other changes recommended in D 202 include revision of the heat stability test and approval of the method of test for fiber analysis of paper and paperboard (D 1030 – 49 T) for application to condenser paper. Work is under way on a method for total chlorides in paper.

Work is continuing on extensive revision in the electrical test methods particularly those for dielectric strength (D 149 – 44) and for power factor and dielectric constant (D 150 – 47 T). Further studies of the recently revised arc-resistance test (D 495 – 48 T) include use of higher current arcs (above 40 ma.), development of a method for providing continuous rate of increase in arc severity, and other forms of arc-resistance test. The test for electrical resistance of insulation (D 257 – 49 T) which was extensively revised last year is being given further study.

The Joint D-9*—D-20 Subcommittee on Conditioning reported on further revisions under consideration in the Tentative Methods of Conditioning Plastics and Electrical Insulating Materials for Testing (D 618 – 49 T). A new section has been formed to revise the present standards for enclosures and conditioning equipment for tests at other than normal temperatures now published under the designations D 760 and D 761.

Annual Meeting of Soap Committee—D-12

COMMITTEE D-12 on Soaps and Other Detergents met on March 21 and 22 at the Hotel Park-Sheraton in New York City.

Several recommendations on standards will be submitted to the Society in the annual report of the committee. Particularly important are the recommendations for proposed tentative specifications for low- and medium-titer solid and chip soap for low-temperature washing. These specifications represent several years of intensive work by the committee.

Recommended for publication as information only are a test for pH of soaps and detergents and the "Ross-Miles" test for foaming of surface-active agents. Although the foaming test, as written, is recognized as applying only under controlled conditions, it is felt that the method represents real prog-

ress in view of difficulty that has been encountered in developing generally acceptable methods for evaluating significant physical properties of soaps and other detergents.

Committee D-20 on Plastics

COMMITTEE D-20 on Plastics held its spring meeting at the Hotel Chamberlin, Old Point Comfort, Va., on March 21 and 22. In addition to the meeting of the main committee there were also meetings of all eleven D-20 working subcommittees. The attendance was over 100 members and guests.

Under the auspices of the Subcommittee on Research, a very interesting papers session was held on Tuesday evening, March 21, at which the following three papers were presented:

"Some Rapid Approximate Statistical Procedures," by Frank Wilcoxon, American Cyanamid Co., Stamford, Conn.

"Characteristics of Carbon Arc Light Sources for Accelerated Exposure Testing," by W. W. Lozier, National Carbon Div. of Union Carbide and Carbon Corp., Fostoria, Ohio.

"The Mechanism of the Degradation of Polyamides," by Frank W. Reinhart, National Bureau of Standards, Washington, D. C.

The Subcommittee on Strength recommended the adoption as standard of the Method of Test for Stiffness in Flexure of Plastics (D 747 – 48 T). This section is studying by round-robin in a number of co-operating laboratories a new falling-ball impact test. A double shear test is also under development as well as a new method for bursting strength. Studies of a new method of tear resistance including the Elmendorf tear tester and the Thwing-Albert tear apparatus are to be made. A new Section on Dynamic Stresses is being organized.

The Subcommittee on Hardness Properties recommended adoption as standard of the Method of Test for Rockwell Hardness of Plastics and Electrical Insulating Materials (D 785 – 48 T). A cooperative study is under way of the Method of Test for Resistance of Transparent Plastics to Surface Abrasion (D 1044 – 49 T) which covers use of the Taber abraser, involving tests in eight laboratories on five sheet materials (cellulose acetate, plasticized and nonplasticized acrylic, polystyrene, and allyl diglycol carbonate). A round-robin study using the Olsen Wearometer and rotating cylinder are also under way on abrasion resistance (mechanical effects). A study of scratch resistance using the Paraffine Company's scratch test is under way.

The Subcommittee on Thermal Properties recommended adoption as standard of the Method of Test for Measuring the Molding Index of Thermosetting Molding Powders (D 731 – 48 T). A revision of the Test for Deformation of Plastics Under Load (D 621 – 48 T) is under way to provide a procedure for classification of polyethylene grades plastics. Further studies of methods for flow of plastics include consideration of the parallel plate plastometer, also capillary rheometry.

An extensive revision of the Tentative Method of Test for Luminous Reflectance and Transmission Characteristics and Color of Plastic Materials (D 791 – 44 T) has been approved by the committee. This method is intended primarily for substantially nonfluorescent plastics but may also be applied to other materials. It is based upon the Hardy type spectrophotometer. The revised method supplements the present A.S.T.M. Standard Method of Test for Spectral Characteristics and Color of Objects and Materials (D 307 – 44). Statements regarding significance of tests were approved for inclusion in the Methods of Test for Index of Refraction of Transparent Organic Plastics (D 542 – 42) and for Surface Irregularities of Flat Transparent Plastic Sheets (D 637 – 43).

In the Subcommittee on Permanence Properties, work is in progress on development of a recommended practice for determining the deterioration of plastics under light exposure tests as well as outdoor exposure tests. A test for volatile loss of plastic materials on exposure to heat is being developed in cooperation with Committees D-9 and D-11. Based on results of a questionnaire on the effect of chemicals on permanence properties, revisions are to be made in the Method of Test for Resistance of Plastics to Chemical Reagents (D 543 – 43). A new method for determining warpage of plastics is being completed, based on the modification of the procedure in Federal Specifications L-P-406a and on the equipment described in the Bureau of Standards plastic wall tile specification. A method for measurement of gas transmission of organic films is under study.

New tentative specifications for cellulose acetate film for primary insulation have been completed. Revisions were accepted in the Specifications for Melamine-Formaldehyde Molding Compounds (D 704 – 44 T).

A heat test method for plasticizers for determining both color stability and acidity increase on heating is under cooperative study. A test for nonvolatile matter is being completed and new wor is to be undertaken on the analysis c vinyl chloride polymers and copoly mers.

A new recommended practice fo injection molding of test specimens wi be issued as tentative. Also new speci fications for a mold for a small wel specimen were submitted as tentative An alternate design of an injection mol for molding test specimens of thermo plastic materials has been approved b committee vote for inclusion in Speci fications D 647. Specifications for dec orative laminates are in preparation.

Structural Sandwich Committee to Present Test Methods Soon

A TWO-DAY meeting o Committee C-19 on Structural Sand wich Constructions was held at A.S. T.M. Headquarters, April 3 and 4 Subcommittee I on Mechanical Proper ties of Basic Materials under the Chair manship of R. C. Platow reviewed and discussed several proposed test meth ods. In considering test methods o physical properties a decision wa reached to omit the determination o absolute specific gravity, confining a proposed method to that of apparen specific gravity only of core materials A proposed method on thermal expan sion was circulated for discussion Additional proposed test methods dis cussed covered bondability, dimen sional stability, and flammability. I was the consensus that all mechanica test methods which have been de veloped by the Forest Products Labo ratory on sandwich constructions can b applied to the testing of core materials All strength test methods under con sideration will conform with the stand ard laboratory atmosphere condition of A.S.T.M. Tentative E 41 – 48 T

Subcommittee II on Mechanical Prop erties of Basic Sandwich Constructio under the acting chairmanship o A. G. H. Dietz, discussed comment received on proposed compression, bend ing, and shear test methods. These in clude compression flatwise and edge wise, bending flatwise, and shear bot flatwise and edgewise. These severa methods will be resubmitted to th committee for letter ballot after rev sions agreed upon. A new propose method of testing for tension flatwis was recommended for submission t ballot of the committee.

Subcommittee III on Permanenc Durability, and Simulated Service und the chairmanship of D. G. Reid, d

oted the majority of its time to discussing the establishment of a program or the determination of atmospheric eterioration of sandwich materials as ell as core materials. A subgroup was ppointed which will make a survey of ne many agencies interested in structural sandwich constructions and materials to obtain opinions on the value f data from exposure of panels alone n comparison with panels used as an ntegral part of a structure. Fatigue esting was also discussed and a subroup was appointed which will perorm a number of round-robin tests sing both the Krause and the Sonntag tigue testing machines. It is planned o formulate a proposed tentative on echanical tests at high- and low-temerature conditions.

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pecifications Receive Attention at Adhesives ommittee Meeting

THE SPRING meeting of ommittee D-14 on Adhesives was held A.S.T.M. Headquarters on March 7 and 28. The first day included meetgs of subcommittees with the advi-ry and main meetings being held on the cond day.

The Subcommittee on Strength Propties reviewed and discussed several roposed new tentative methods inuding a test for strength properties of dhesives in shear by flexural loading. he two shear strength tentative ethods (now published) were recomended for advancement to standard. ound-robin tests in progress on plastic--plastic adhesive strengths were disussed. A clarification of the jig deription in the impact strength test ethod was approved and will be bmitted to letter ballot.

The Subcommittee on Working Propties presented two additional methods r consistency which were approved for tter ballot. A modification of the reen tack meter was discussed and und-robin tests were arranged in hich the instrument will be used for taining additional data. A proposed ocking test method was recommended r letter ballot.

Important sessions were held by the bcommittees on Permanence and ecifications. A proposed tentative ethod of Test for Resistance of Adsives for Wood to Cyclic Accelerated rvice Conditions was discussed and commended for letter ballot along ith a proposed Tentative Method for ontinuous Exposure to Temperature d Humidity. A third method under the jurisdiction of the Subcommittee on Permanence was recommended for committee letter ballot, this being a Tentative Method of Test of the Permanence of Adhesives in Various Biological Environments. A proposed tentative specification for adhesives for acoustical materials was reviewed and recommended for adoption after revisions which would make this specification applicable only to clean uncoated surfaces. An additional revision will include the alternative of using disks of materials other than as specified when agreed upon by the manufacturer and consumer.

A section is collecting data for the purpose of writing a specification covering the use of adhesives in bookbinding, the data to consist essentially of a list of properties involved in this particular use. A definite need was expressed for a specification to cover the use of adhesives in packaging, especially for domestic shipments.

An interesting session of the Subcommittee on Research included presentation by several members of new techniques in testing the adhesion of materials. Of considerable interest was an explanation of a new application in soldered scarf joints using antimony.

The concluding item on the committee program was a talk presented by N. V. Poletika, Timber Engineering Co., who discussed a course on glue testing which is being conducted by his organization.

Testing Exhibit (*Continued from p. 12*)

Tagliabue Instruments Division
Weston Electrical Instrument Corp.
Booth 31

Some of the latest developments in the TAG line of industrial and laboratory testing instruments will be displayed in this booth. In addition, TAG A.S.T.M. thermometers and A.P.I. hydrometers will be shown. The presentation will include an interesting panel on which are mounted a general assortment of laboratory thermometers and hydrometers. Additional items of interest will be found in the TAG instruments for testing petroleum products. Among these will be shown the new TAG Colorimeter Stand with the TAG-Saybolt Chromometer and a TAG-Saybolt Thermostatic Viscosimeter.

Thwing-Albert Instrument Co.
Booth 21

This company will demonstrate testers of interest to a great variety of manufacturers and processors. Instruments on display will measure tensile strength, tearing resistance, modulus of rupture of paraffin wax, pickling rate of canners steel, softness-stiffness of paper, textiles and plastic films, moisture vapor permeability, liquid penetration, temperature with bolometers, and resistance bulbs. Model L-50 Sentronic Recorder will highlight the exhibit with a display of sensitivity, speed, and versatility suggesting many applications.

Arthur H. Thomas Co.
Booth 12

On display will be: Model B Beckman Glass Prism Spectrophotometer.—An effective band width of 5 millimicrons or less can be obtained over the spectral range of 320 to 1000 millimicrons; Beckman Automatic Titrator—For pH or redox; Lindberg High Frequency Combustion Unit—For determination of carbon and sulfur in iron, steel, and heat resistant alloys; Stormer Viscosimeter with Stroboscopic Timer which gives visual indication of rotational speed of 200 rpm. as required in determining the consistency of paints by the A.S.T.M.; Electrographic Kit—For rapid identification of metallic elements in metals, alloys, or surface platings, by means of anodic solution and deposition on a suitable carrier such as paper.

Will Corporation
Booth 50

In this booth the first of a new, streamlined design series of Analytical Balances, the new Becker Model AB-2 will be shown. The latest Beckman offering to the testing laboratory—the Automatic Titrator—will be demonstrated as will be the new Lindberg Model HF Induction Furnace. A Metallographic Microscope with Camera Attachment, a Refractometer, and Viscometer will be among the apparatus demonstrated.

Wilson Mechanical Instrument Co.
Booth 17

This display will include the Rockwell Hardness Tester, which is used for testing the hardness of all metals, such as tools, dies, heat-treated steel parts, brass, bronze, etc.; the Rockwell Superficial Hardness Tester for testing thin materials, superficially hardened surfaces, such as nitrided steels, thin carburized parts, etc.; and the new manually operated Model MO Tukon Tester—this latter piece of equipment to be exhibited for the first time. This machine applies loads of from 1 to 1000 g. and includes a number of features.

The Young Testing Machine Co.
Booth 16

On display will be many items of the Company's testing machine and strain gage equipment. Four complete lines of Universal Testing Machines are available, which allows a complete selection of testing machines from lap ram machines to large, heavy-duty machines, incorporating a separate hydraulic weighing capsule. A full line of testing machine accessories and a photoelastic machine which has great flexibility and versatility will be shown. Many new instruments will be on exhibition, including scanning units for scanning up to 72 gages per second and dynamic recorders capable of recording strain gages directly on a strip chart up to 100 cycles per second. A Multiple Channel Recorder, capable of recording 12 independent curves from individual strain gages will also be on display.

Series of A.S.T.M. Steel Bar Specifications Cover Most Applications

1949 Book of A.S.T.M. Standards Includes a Complete Group of General-Purpose Bar Specifications

By E. V. Bennett, Chairman, Subcommittee XV on Bar Steels, Committee A-1

For many years consumers and producers of steel have recognized the A.S.T.M. as a leading specification-writing body. Its specifications cover a broad list of engineering and constructional steel products including plates of all kinds, structural shapes, concrete reinforcing bars, tubular products, castings, forgings, and countless other items. Where bar products are concerned, however, the Society until recently has had available only two bar specifications covering the chemical compositions of hot-rolled and cold-finished material. There have been persistent requests from materials engineers and buyers, and steel metallurgists as well, that A.S.T.M. develop adequate specifications for carbon-steel and alloy-steel bars.

These products represent about 15 per cent of the total tonnage rolled by the steel industry.

Throughout recent years, possibly 75 per cent of carbon-steel and alloy-steel-bar tonnage has been ordered to standard *chemical* ranges with no other stated requirements. Other requirements such as check analysis, dimensional tolerances, and general inspection are not specified, and in these cases A.I.S.I. steel product manuals usually have been referred to as a guide.

The new group of A.S.T.M. bar specifications now provide all requirements in compact, convenient form. In addition to these essential purchase requirements, most steel producers require specific end use details on each order to aid them in proper processing.

Scope of A.S.T.M. Work

Committee A-1 on Steel, through its Subcommittee XV on Bar Steels, has been working for several years to provide more adequate specification coverage. Several new specifications have been written, others revised, and are now available in the 1949 Book of A.S.T.M. Standards, Part 1, covering

TABLE I.—SUMMARY OF A.S.T.M. CARBON-STEEL BAR SPECIFICATIONS.

Specification Title and A.S.T.M. Designation	Chemical Requirements		Size Limitations and Diameters	Mechanical Properties				
	Regular	Free-Cutting		Tensile Strength, psi.	Yield Point, min., psi.	Elongation, min. per cent in 8 in.	Elongation, min. per cent in 2 in.	Reduction of Area, min., per cent
Hot-Rolled Carbon-Steel Bars (A 107 – 49 T)	Open Hearth 1008 1040 1010 1045 1015 1050 1016 1055 1020 1060 1022 1070 1025 1080 1030 1095 1035 Bessemer B1010	Open Hearth 1115 1117 1118 1120 1137 1141 1151 Bessemer B1111 B1112 B1113	All sizes	None specified				
Medium-Carbon-Steel Bars Subject to Mechanical Property Requirements (A 306–49 T)	All grades C, Unspecified Mn, 0.90 max. P, 0.040 max. S, 0.050 max. Si, 0.10 min.	None	All sizes					
Grade 70	...	...	...	70 000 to 85 000	36 000	14	18	
Grade 75	...	...	...	75 000 to 90 000	38 000	12	16	None specified
Grade 80	...	...	...	80 000 min.	40 000	10	14	
				(Added bend test required for each grade)				
Heat-Treated Carbon-Steel Bars (A 321–49 T)	C, 0.50 max. Mn, 0.60 to 0.90 P, 0.04 max. S, 0.05 max. Si, 0.15 to 0.30	None	4 in. and under Over 4 to 7 in., incl.	90 000 min. 85 000 min.	55 000 50 000	.. ..	20 20	40 40
Cold-Finished Carbon-Steel Bars and Shafting (A 108–49 T)	Open Hearth 1008 1025 1010 1030 1015 1035 1016 1040 1018 1045 1020 1050 1022 1095 Bessemer B1010	Open Hearth 1115 1117 1118 1141 1144 1151 Bessemer B1111 B1112 B1113	All sizes	None specified				
Stress-Relief-Annealed Cold-Drawn Carbon-Steel Bars (A 311–49 T)	None	1137	9/16 in. and under Over 9/16 to 1¼ in., incl. Over 1¼ to 2½ in., incl.	100 000 min. 95 000 min. 90 000 min.	80 000 75 000 70 000	.. .. ..	15 15 14	40 40 40
		1141	9/16 in. and under Over 9/16 to 1¼ in., incl. Over 1¼ to 2½ in., incl.	105 000 min. 100 000 min. 95 000 min.	85 000 80 000 75 000	.. .. ..	12 12 12	40 40 40
		1144	9/16 in. and under Over 9/16 to 1¼ in., incl. Over 1¼ to 2½ in., incl.	105 000 min. 100 000 min. 95 000 min.	85 000 80 000 75 000	.. .. ..	12 12 12	35 35 35
		1151	9/16 in. and under Over 9/16 to 1¼ in., incl. Over 1¼ to 2½ in., incl.	105 000 min. 100 000 min. 95 000 min.	85 000 80 000 75 000	.. .. ..	10 10 10	35 35 35

rous metals. These eight standards e also printed in separate pamphlet m.

In order that Subcommittee XV ould have adequate representation of ajor interests concerned, it was greatly panded a few years ago and now in- ides 26 consumers and general-inter- members, and 19 representatives of oducers of carbon- and alloy-steel rs. The consuming group includes tallurgists or materials engineers m the following: six manufacturers electrical equipment; five cold finish- ; five miscellaneous manufacturers of arings, chain, bolts, saws and busi- ss machines; three railroads; three ricultural implement makers; and ir general-interest members.

The diversity of membership insures mplete discussion of all phases of a r specification before approval. The odus operandi of the Society gives e user of A.S.T.M. standards two advantages: first, the representation from producing and using interests assures a complete examination of both sides of the specification-writing picture; and secondly, Society procedure is such that specifications must "season" for a sufficient period before being advanced to standard status.

Standard Practice is Basis of A.S.T.M. Steel Requirements

There is also a further angle which, while not of primary importance to the engineer, certainly is of major interest to the buyer and the cost estimator. As far as practicable for general-purpose applications, A.S.T.M. specifications are usually recognized by the trade as incorporating standard practices. Special-purpose specifications involving unnecessarily restrictive requirements are, in general, avoided. However, where unusually stringent requirements are necessary for some specific end use, A.S.T.M. standards serve a widespread need in providing a base on which supplementary testing or more restricted requirements can be imposed.

Who Needs A.S.T.M. Specifications?

A.S.T.M. specifications should be of particular interest to the following types of steel consumers:

1. *The large user of steel* who usually employs a competent metallurgical staff. The metallurgist wisely reviews current A.S.T.M. standards and utilizes them *in toto* or uses those portions which fit his company's particular needs and end products. Ultimately this information is usually incorporated into complete purchasing department specifications.

2. *The small purchaser* who has no available trained metallurgical personnel. A.S.T.M. standards provide a con-

TABLE II.—SUMMARY OF A.S.T.M. ALLOY-STEEL BAR SPECIFICATIONS.

Specification title and A.S.T.M. designation	Chemical Requirements	Size Limitations and Diameters	Mechanical Properties				
			Tensile Strength, min., psi.	Yield Point, min., psi.	Elongation in 2 in., min., per cent	Reduction of Area, min., per cent	Brinell Hardness
...t-Rolled Alloy-Steel Bars (A 322–49 T)	1330, 1335, 1340 2317, 2340 2515 3130, 3135, 3140, 3141, 3150 E3310 4017, 4023, 4024, 4027, 4028, 4032 4037, 4042, 4047, 4063, 4068 4130, 4140, 4142, 4145, 4147, 4150 4320, 4340 4615, 4620, 4640 4815, 4820 5132, 5135, 5140, 5145, 5147, 5150, 5152 6150, 6152 8620, 8630, 8635, 8640, 8641, 8650, 8653, 8655 8720, 8740, 8745, 8750 9255, 9260, 9261, 9262 E9310 9440, 9445	All sizes	None specified				
...at-Treated Alloy-Steel Bars (A 286–46 T)	(Carbon not specified)						(When specified)
Class A	2300, 3100, 4100, 8700	2½ in. and under	105 000	80 000	20	50	..212 to 269
		Over 2½ to 4 in., incl.	100 000	75 000	20	50	
		Over 4 to 7 in., incl.	95 000	75 000	20	50	
Class B	2300, 3100, 4100, 8700, 4300, 9800	2½ in. and under	125 000	105 000	16	50	..235 to 311
		Over 2½ to 4 in., incl.	115 000	90 500	16	45	
		Over 4 to 7 in., incl.	110 000	85 000	16	45	
...oy-Steel Rounds, ...uitable for Oil-...Quenching to ...nd-Quench ...Hardenability ...Requirements ...A 304–47 T)	1340H 2340H 3140H, 3150H 4042H 4140H, 4150H 4340H 4640H 5140H, 5150H 6150H 8640H, 8650H 8740H, 8750H 9440H 9840H, 9850H	1 to 4-in. rounds	None required but hardenability specified for each analysis				
...ld-Finished ...Alloy-Steel Bars ...designation in ...process of prep- ...aration)	2317 2515 3120, 3130, 3135, 3140, 3150 E3310 4023, 4024, 4037, 4042, 4063, 4068 4130, 4140, 4142, 4145, 4150 4320, 4340 4615, 4620, 4640 4815, 4820 5120, 5140, 5150 6120, 6150 8620, 8630, 8640, 8653, 8655 8740, 8742 9260 E9310	All sizes	None specified				

venient and probably the best available guide today in ordering steel.

3. *The steel warehouse* is confronted with the problem of stocking steels for miscellaneous end usage. A.S.T.M. provides a useful standard, universally understood and accepted by industry in general. It is also frequently desirable to advertise that available warehouse stocks meet certain A.S.T.M. standards.

4. *Export business* usually requires a "meeting of minds" on some commonly accepted standard such as A.S.T.M. specifications.

5. *Company specifications* generally can be translated to similar A.S.T.M. specifications. From this transfer there will develop greater ease of procurement and better possibilities of dealing with new supply sources not presently familiar with the particular requirements. Maintenance of quality can be improved. A thorough study of the material regularly offered under A.S.T.M. specifications can even present the possibilities of economies because standard goods are generally cheaper than specials.

Scope of Present A.S.T.M. Bar Specifications

Going from the realm of generalities into the specific field of currently available A.S.T.M. bar specifications, the 1949 Book of A.S.T.M. Standards contains the following carbon-steel bar specifications:

Hot-Rolled Carbon-Steel Bars (A 107 – 49 T)
Heat-Treated Carbon-Steel Bars (A 321 – 49 T)
Medium Carbon-Steel Bars Subject to Mechanical Property Requirements (A 306 – 47 T)
Cold-Finished Carbon-Steel Bars and Shafting (A 108 – 49 T)
Stress-Relief Annealed Cold-Drawn Carbon-Steel Bars (A 311 – 49 T)

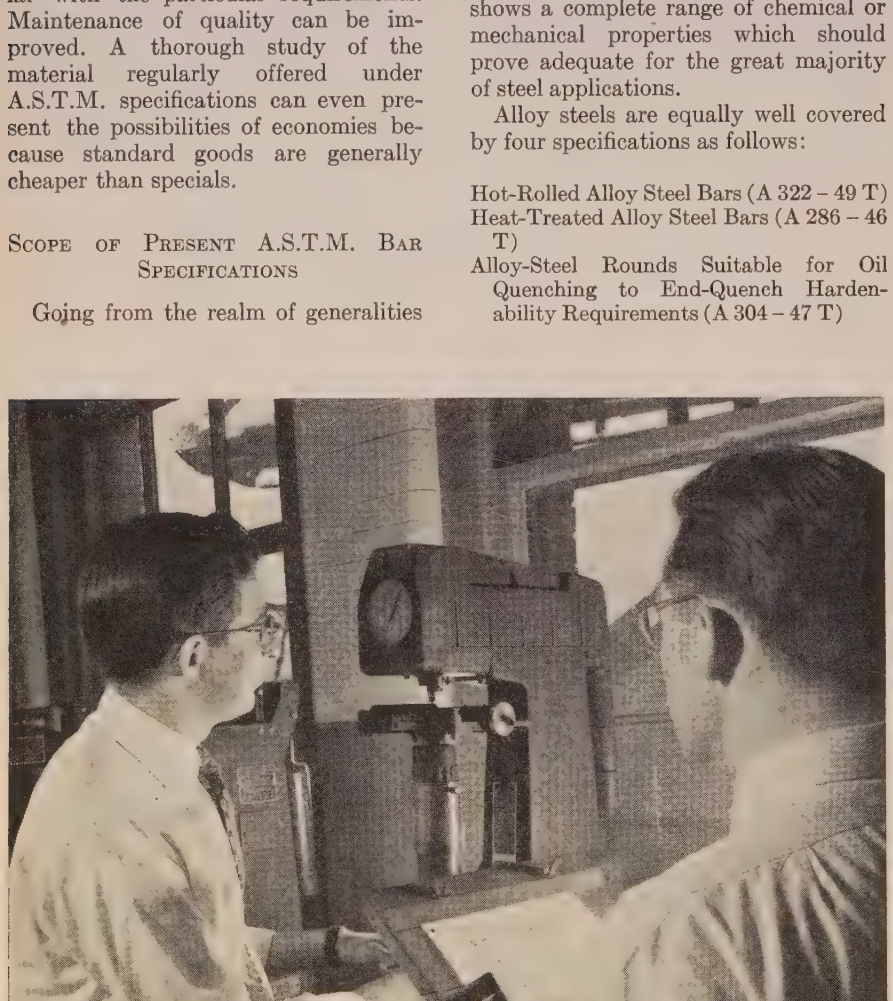
The requirements of each of these specifications, together with the proper A.S.T.M. designation, are summarized in Table I. Each of these specifications shows a complete range of chemical or mechanical properties which should prove adequate for the great majority of steel applications.

Alloy steels are equally well covered by four specifications as follows:

Hot-Rolled Alloy Steel Bars (A 322 – 49 T)
Heat-Treated Alloy Steel Bars (A 286 – 46 T)
Alloy-Steel Rounds Suitable for Oil Quenching to End-Quench Hardenability Requirements (A 304 – 47 T)
Cold-Finished Alloy-Steel Bars (in th course of preparation)

In a like manner, the requirements these alloy specifications are summarize in Table II. Alloy steels are normal not supplied to hot-rolled mechanic properties, hence the omission of specification along these lines.

In addition to the chemical and m chanical requirements summarized two tables, the respective specificatio where appropriate, cover bending d tails, requirements on straightness, pe missible variations in dimensions, mar ing, and acceptable inspection pr cedure. A review of the specificatio should readily reveal to those who pr duce and use steel bars that the stan ards now available adequately cov most of the conventional applications



Making a Hardenability Test to Determine Compliance with Specification A 304.

A.S.T.M. Rubber Protective Equipme Standards Approved by A.S.A.

The four Standard Spec fications for Rubber Insulating Blanke (D 1048 – 49 T), Insulator Hoods (1049 – 49 T), Insulating Line Ho (D 1050 – 49 T), and Insulating Sleev (D 1051 – 49 T), have been approved b the American Standards Associatio Those concerned with the procureme and use of materials for the protecti of electrical workers will find these spec fications convenient to use since th have been printing in one documer They were prepared by the A.S.A. Se tional Committee J6, functioning und the joint sponsorship of A.S.T.M. a the Edison Electrical Institute. Bef their revision by Committee J6, t standards were issued as Americ War Standard Specifications for Lin men's Rubber Protective Equipment.

University of Utah Centennial

On invitation from University of Utah the Society was rep sented at the recent commemorating ex cises in connection with the Centenn Program. E. H. Beckstrand, a mem of A.S.T.M. since 1907 and Professor Mechanical Engineering (Retired), U versity of Utah, represented the Socie and with Mrs. Beckstrand attended various exercises. Many societies a associations for the advancement of lea ing were represented, and A.S.T.M. pleased that it could take part. W the University was chartered in 1850 population of the whole state was ab 10,000, which is now the approxim registration of students at the Univers

ERSONALS • • •

News items concerning the activities of our members will be welcomed for inclusion in this column.

OTE—These "Personals" are arranged in order of alphabetical sequence of the names. quently two or more members may be referred to in the same note, in which case the first named is used as a key letter. It is believed that this arrangement will facilitate rence to the news about members.

t the annual meeting of the American crete Institute in Chicago in Febru- **Frank H. Jackson,** Principal Engineer ests, Bureau of Public Roads, Washing- D. C., was elected President for the ing year, and **A. T. Goldbeck,** Engi- ing Director, National Crushed Stone n., Washington, D. C., was elected for a -year term as Vice-President. The wing were elected to three-year terms directors: **A. E. Cummings,** Research ineer, Raymond Concrete Pile Co., York City; **I. L. Tyler,** Portland ent Assn., Chicago, Ill.; **Charles S. tney,** Consulting Engineer, Milwaukee ; and **C. E. Wuerpel,** Technical Direc- Marquette Cement Manufacturing Chicago.

amuel Albert Abrahams, formerly nager of Manufacture, Insulations ., The Paraffine Cos., Inc., Emeryville, f., is now Division Manufacturing nager, The Philip Carey Manufactur- Co., Plymouth Meeting, Pa.

ryson B. Beckwith is now associated Commonwealth Industries, Detroit, h., as Sales Engineer. He was for- ly Metallurgical Engineer, Vanadium o. of America, in the same city.

ichard A. Biggs, formerly Develop- t Engineer of Pittsburgh Corning o., has been appointed Director of itectural Development, Stainless Sales ., Crucible Steel Company of America, headquarters in New York City. cible is intensifying and expanding its ices, such as application engineering, arch and development in specialty ls, for architects, engineers, builders, manufacturers of building materials. Biggs' participation in A.S.T.M. vities includes technical committee nments on insulation, methods of ing structures, structural sandwich truction, and the advisory committee orrosion.

harles W. Blacketer, formerly Man- of the Customer Service Department, been appointed Technical Director of Stamford, Conn., branch of Atlas der Co.'s Industrial Finishes Depart- t. Mr. Blacketer became associated the Atlas Co. last year after extensive erience with Berry Bros., Sherwin- liams, and Diamond Alkali Co.

Walter Bonsack has been named Vice- sident and Director of Research for the ristiansen Corp., Chicago, Ill. He will d technical operations and procedures all of the company's plants and will be ted at the Chicago headquarters.

Gilbert K. Brower, formerly Vice-President, Manufacturing, John L. Ray Oil Corp., South Braintree, Mass., is now Technical Director, Kelite Products, Inc., Montauk, L. I., N. Y.

Franklin H. Fowler, Jr., is now affiliated with Engineering Research Associates, Inc., St. Paul, Minn., as Mathematician. He was previously Associate Editor, McGraw-Hill Publishing Co., New York City.

D. L. Getz, Chief Engineer, Steel Products Engineering Co., Springfield, Ohio, has been named Chairman of the Engineering and Research Committee of the Stoker Manufacturers Association.

E. W. Gilliland, formerly Chief Chemist, Mine Safety Appliances Co., Pittsburgh, Pa., is now associated with the John T. Ryan Memorial Lab., Pittsburgh, in a similar capacity.

Ralph E. Hall, international authority on industrial and municipal water-conditioning, and Director of Hall Laboratories, Inc., Pittsburgh, Pa., since it was founded in 1925 by the Hagan Corporation, was honored recently at a dinner of 150 associates and friends at the St. Clair Country Club, Pittsburgh. Following the dinner 52 executives, veteran employees, and district managers of Hall Laboratories, Inc., participated in a four-day silver-anniversary celebration program, which included a 3000-mile round trip to Florida. Dr. Hall announced that although he will continue his scientific work as consultant with the firm and remain a member of the board of directors, he is relinquishing active direction of Hall Laboratories, Inc., to **Everett P. Partridge,** who has been Director of Research for many years. In A.S.T.M. Dr. Hall has rendered outstanding service, particularly in connection with Committee D-19 on Industrial Water, of which he has been the Secretary since the committee was organized in 1932.

Arthur Leland Johnstone, formerly Senior Testing Engineer, Kansas City Public Works Testing Lab., is now associated with the Searle Petroleum Co., Omaha, Nebr.

Paul E. LaValley has accepted position as Chief Engineer, Charles Howe Associates, Inc., Newburyport, Mass. He was previously a member of the technical staff of Sylvania Electric Products, Inc., Ipswich, Mass.

William F. Little, Engineer in Charge, Photometric Department, Electrical Testing Laboratories, Inc., New York City, has been named by the Illuminating Engineering Society to receive its 1950 Gold Medal, presentation to be made during the National Technical Conference at Pasadena, Calif., Aug. 21–25. The Gold Medal, highest honor in the field of illumination, is awarded "for meritorious achievement conspicuously furthering the profession, art or knowledge of illuminating engineering."

Raymond McBrian, Vice-President, Denver and Rio Grande Western Railroad Co., Denver, Colo., participated in the Panel Discussion on Diesel Engine Maintenance, at the Twelfth Annual Meeting of the Midwest Power Conference held in April in Chicago under the sponsorship of the Illinois Institute of Technology, with the cooperation of the engineering departments of several of the midwestern colleges and universities, and local sections of various technical organizations.

Carl S. Miner, Director of Miner Laboratories, Chicago, has been elected to the Board of Directors of Commercial Solvents Corp., Terre Haute, Ind. Mr. Miner, in his capacity as consultant, serves on the research committees of a number of corporations.

Russell F. Passano, formerly Metallurgical Engineer, Bethlehem Steel Co., Inc., Bethlehem, Pa., has become a member of the staff of Coverdale & Colpitts, Consulting Engineers, New York City.

D. J. Peeps, formerly Chief Engineer, has been advanced to Vice-President in Charge of Engineering of the DeVilbiss Co., Toledo, Ohio.

John H. Sandberg is now associated with the Mission Mfg. Co., Houston, Tex., in the capacity of Metallurgist.

Paul Schwarzkopf, Director of Research, American Electro Metal Corp., Yonkers, N. Y., delivered the sixth annual medal lecture sponsored by the Powder Metallurgy Laboratory, Stevens Institute of Technology, Hoboken, N. J., the title of his paper being "Mid-Century Review and Preview of Powder Metallurgy." Dr. Schwarzkopf has been a pioneer for 30 years in the powder metallurgy field.

Raymond B. Stringfield, Consulting Chemical Engineer, Los Angeles, and Past-Chairman of the A.S.T.M. Southern California District, has been honored by the Los Angeles Rubber Group through election as an honorary life member. He has been active in this group for over 20 years and was its first chairman in 1928. The Rubber Group's annual publication indicates that this honor was conferred on him "for his unselfish efforts, for the inspiration he has been to all with whom he worked, and because we consider him an esteemed friend and welcome companion."

Percival Theel, who previously headed the chemistry and dyeing department at Philadelphia Textile Institute, has been appointed Coordinator of Research. **B. Russell Koenig,** associate professor in charge of Jacquard color, testing and microscopy, has been named Assistant Coordinator of Research.

Sam Tour, Chairman of the Board of Sam Tour and Co., Inc., has just been elected Chairman of the Inter-Society Corrosion Committee of the National

Association of Corrosion Engineers, a committee organized several years ago to promote cooperation among technical societies working in the field of corrosion. Mr. Tour has maintained an active interest in the field of corrosion since World War I, is a staunch A.S.T.M. supporter and has established a Sam Tour Award Fund to promote interest in corrosion testing and to offer some incentive for the publication of papers on corrosion testing in the A.S.T.M.

Howard Vogel, Chief Engineer of Champion Spark Plug Co., Toledo, Ohio, has been named to the newly created post of Director of Engineering, with Roy Paton as his assistant. Mr. Vogel, who has been with Champion for 18 years and has been Chief Engineer since 1946, will maintain his position of directing the over-all engineering operation. Paton, who has been in charge of the engineering production, joined the company in 1946. He will perform most of his duties in the field with manufacturers using Champion equipment.

James R. Withrow, Professor Emeritus in the School of Chemistry and Chemical Engineering of Ohio State University, was honored recently by presentation of honorary membership in the American Institute of Chemists. Presentation was made at the first annual meeting of the Ohio chapter of A.I.C.

The Inter-Society Color Council, of which A.S.T.M. is a member, has announced that the Council Chairman for 1950 is **Isay A. Balinkin,** who represents the American Ceramic Society on the Council. He is associated with the Department of Physics of the University of Cincinnati.

NEW MEMBERS...

The following 62 members were elected from March 23, 1950 to April 20, 1950 making the total membership 6721 . . . welcome to A.S.T.M.

Note—Names are arranged alphabetically—company members first, then individuals

Chicago District

SPECIALLOY, INC., Mitchell Silverstein, Vice-president, 336 W. Thirty-seventh St., Chicago 9, Ill.

DINSDALE, DAVID A., Engineer, Materials, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill. For mail: 2233 S. Throop St., Chicago 8, Ill.

FRANTZ, NICHOLAS, Chief Engineer, Carter Parts Co., 213 Institute Pl., Chicago 10, Ill.

Cleveland District

BOWERS, A. G., Chief Chemist, Hunt Manufacturing Co., Lisbon Rd., Cleveland 4, Ohio.

FRIEDLY, GLENN C., Manager, District Sales and Research Director, Lexington Supply Co., 4815 Lexington Ave., Cleveland, Ohio. [J]*

HOBBS, GEORGE S., Engineer, 60 Wood St., Painesville, Ohio.

JUVE, R. D., Chief Chemist, Mohawk Rubber Co., Akron, Ohio.

Detroit District

KITTLE, KEITH B., Heating Engineer, Fairbanks, Morse and Co., 616 Fourth, Three Rivers, Mich. For mail: 210 Fifth Ave., Three Rivers, Mich.

New England District

LIBERTY MUTUAL INSURANCE CO., Stuart W. Gurney, Director of Industrial Hygiene, 175 Berkeley St., Boston 17, Mass.

LAAFF, GEORGE S., Director, Research and Development, The Bolta Co., Lawrence, Mass.

New York District

BUILDING OFFICIALS CONFERENCE OF AMERICA, INC., Arthur J. Benline, Second Vice-President; Superintendent of Housing and Buildings, Municipal Bldg., New York 7, N. Y.

EDUCATIONAL AND INSTITUTIONAL COOPERATIVE SERVICE, INC., Leslie F. Robbins, Secretary, 45 Astor Pl., New York 3, N. Y.

GRAVES, H. K., Materials Engineer, Material Lab., New York Naval Shipyard, Brook N. Y.

KLING, GEORGE, Superintendent, Dep ment of Streets and Highways, Swanst Pl., Union, N. J.

MORRIS, ARTHUR D., President, Bayo Bolt Corp., 90 West St., New York 6, N

PARSONS, FRANK E., Engineer, Nati Mineral Wool Assn., 2906 R.K.O. Bl New York, N. Y.

SODERGREEN, A. L., Director, Chem Dept., West Disinfecting Co., 42-16 W St., Long Island City, N. Y.

WHITE, ROBERT T., Building Inspector, of East Orange, City Hall, East Ora N. J.

Northern California District

PHILLIPS, ARIS, Acting Assistant Profes Stanford University, 262 Mechanical gineering Dept., Stanford, Calif.

Ohio Valley District

INDIANA MINERAL AGGREGATES ASSN., I Ralph E. Simpson, Engineer-Direc 1207 Roosevelt Bldg., Indianapolis 4,

AVRIL, ARTHUR C., President, Sakrete, I Box 11, St. Bernard, Cincinnati 17, Oh

BEARD, MAX I., Metallurgist, Automo Gear Works, Inc., 1500 S. O St., R mond, Ind. For mail: 225 S. Twelfth Richmond, Ind.

MCKIM, WALTER A., Assistant to Presid Reliance Varnish Co., 4730 Critten Dr., Louisville 9, Ky.

PERENY, LOUIS, President, Protective Tr ments, Inc., 420 Dellrose Ave., Dayto Ohio.

Philadelphia District

FOSTER & KESTER CO., INC., E. How Kester, Vice-President, 2601 N. Broad Philadelphia 32, Pa.

REVONAH SPINNING MILLS, Fred J. M Donald, Chemist, Hanover, Pa.

CAUM, J. W., Technical Assistant, Ameri Society for Testing Materials, 1916 R St., Philadelphia, Pa. For mail: Castlewood Rd., Glenside, Pa.

FITTERER, SHELDON EDWARD, Technical sistant, American Society for Testing terials, 1916 Race St., Philadelphia 3, For mail: 603 Central Ave., Hollo Terrace, New Castle, Del.

KELEMEN, FRANK K., General Mana K.S.M. Products, Inc., Merchantvill N. J.

MARKHOFF, C. E., Laboratory Group Lea The Borden Co., Chemical Div., Summerdale Ave., Philadelphia 24, Pa

MINNICK, L. JOHN, Chief Chemist, G. & H. Corson, Inc., Plymouth Meeting, P

SORENSEN, WILLIAM R., Quality Control gineer, York Corp., York, Pa., For m 1404 Second Ave., York, Pa.

URBANEK, JOSEPH P., Chemist, Philadel Quartermaster Depot, Research and velopment Labs., 2800 S. Twentieth Philadelphia 45, Pa.

Pittsburgh District

DICKSON, K. B., Manager, Bureau of T

To the A.S.T.M. Committee on Membership

1916 Race St., Philadelphia 3, Pa.

Gentlemen:

Please send me information on membership in A.S.T.M. and include a membership application bl

Signed _____

Address _____

Date _____

al Information, Carnegie-Illinois Steel rp, 434 Fifth Ave., Pittsburgh, 30, Pa.
SHALL, TOM, JR., Chemist, City of Pittsrgh, 4501 Centre Ave., Pittsburgh 13,

ouis District

DIX AVIATION CORP., KANSAS CITY DIVIN, H. K. Morgan, Director of Engineert, Box 1159, Kansas City 10, Mo.

ern California District

HERN CALIFORNIA GAS CO., Guy Cord, Research Engineer, Box 3249, Termi Annex, Los Angeles 54, Calif.
T, RAYMOND A., Director of Research l Development, Aluminum Div., Hunter uglas Corp., Riverside, Calif.
NAVAL ORDNANCE TEST STATION, Inyon, China Lake, Calif.

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* [J] denotes Junior Member.

LABORATORY SUPPLIES . . .

Catalogs and Literature and Notes on New or Improved Apparatus

Note—This Information is based on literature and statements from apparatus manufacturers and laboratory supply houses.

Catalogs and Literature

A. S. Aloe, 1831 Olive St., St. Louis 3, Mo. A 64-page Supplementary Catalog 102 A, to be used with the large General Laboratory Catalog 102, gives detailed specifications on some important apparatus recently added to Aloe's line. The catalogs represent a single source for all laboratory needs—laboratory furniture, apparatus, and chemicals.

Bausch & Lomb Optical Co., Rochester 2, N. Y. Laboratory Microscope Catalog, D-185, describes the new Model FL Student Microscope as an inexpensive adjunct to B & L's regular line of laboratory-type instruments. All these microscopes are available with conventional substage mirror, integral substage illuminator, or both. There are no catalog numbers listed—a standardized method of model designations makes for quicker and more accurate ordering. 24 pages, 8½ by 11 in.

Also Catalog D-1010, in which there is a new Series of Research Microscopes, Series E, added to the well-known Series CC and DDE. 20 pages, 8½ by 11 in.

Corning Glass Works, Laboratory Dept., Corning, N. Y. A ten-page supplement B, Catalog No. LP28, contains two sections, Section I—New Items, and Section II—Discontinued Items. The new items include details on PYREX ball and socket joints, and VYCOR brand high-vacuum stopcocks and tubing. Corning is discontinuing the manufacture of No. 650 Bottles sizes 36 ml. and 60 ml.

Scientific Glass Apparatus Co., Inc., 49 Ackerman St., Bloomfield, N. J. A new 48-page catalog (No. 50), entitled "Glass Blowing Equipment," illustrates and describes many of the thousands of stock items carried, with appended tables giving detailed specifications and current prices. One section of the catalog is devoted to all types of stopcocks. Another section deals with vacuum equipment—shows vacuum pumps, testers, and gages. Pyrex brand glass tubing, rods, and seals are also covered by the new catalog, as well as glass blowing burners, etc. A number of specialties are also listed, such as patented automatic acid and alkali burettes, Theimer Vacuum Adapters, bell jars, and the Vanderkamp "Melt-Pointer." A complete subject and numerical index is included.

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the A.S.T.M. Committee on Membership, 1916 Race St., Philadelphia 5, Pa.

ntlemen:

Please send information on membership to the company or individual indicated below.

_____

_____

This Company (or individual) interested in the following subjects: (indicate field of activity, that is, roleum, steel, non-ferrous, ect.,)

_____

Signed _____

Address _____

:e _____

Instrument Notes

Concrete Tester—The Baldwin Locomotive Works, Testing Equipment Dept., Philadelphia 42, Pa. A new concrete and cement testing machine of 300,000 lb. capacity has as its principal feature as compared with the previous design separate loading and weighing units. This prevents the transmission of load shocks to the indicators. The two-unit design also permits varying their relative positions to suit conditions of use and protects the operator from flying or falling particles of breaking specimens. The new testing machine is a hydraulic compression-type suitable for standard concrete cylindrical test specimens 3 in. by 6 in., 6 in. by 12 in., and 8 in. by 16 in. Special bearing blocks are available for testing building blocks 12 in. wide and 18 in. long. These blocks may also be used for testing cylindrical specimens. The rate of load application is controlled by means of a pacing indicator and manually operated valve which varies the pump discharge to the hydraulic loading cylinder. Load can be increased at a constant rate in unit stress per minute on the test specimen with minimum manipulation of controls. The pacing device operates at standard A.S.T.M. loading rates on the 50,000-lb. dial for 2-in. and 3-in. diameter cylinders, and on the 300,000-lb. dial for 6-in. and 8-in. diameter cylinders.

Telereader—Consolidated Engineering Corp., 620 N. Lake Ave., Pasadena 4, Calif.—The Telereader, Consolidated Type 25-105, offers a rapid and precise means of measuring, analyzing, and tabulating data from oscillographic records, either on film or paper. The image is magnified 2.5 times and projected on a 15- by 30-in. ground-glass screen, together with the image of manually adjustable reading crosswires.

Electroviscometer—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa. Viscosity measurements directly in centipoise units and without the need for calculations are now provided for the first time. The instrument provides highly reproducible results, has sensitivity over its full range, and is simple to operate. It is useful for testing any liquid of the free-flowing Newtonian type. It comprises a stand on which the sample is held in a sample cup and revolved at constant speed around a "bobbin." This central element is movable and can be turned in opposition to the natural pull of the liquid under study as shearing force is exerted against the bobbin. A magnetic field, to which variable amounts of electrical force can be applied, is created around the bobbin adjustive by control knobs on the separate power supply and meter unit. When the magnetic force applied to the bobbin exactly counterbalances the mechanical force exerted by the rotating liquid, the viscosity is expressed in centipoise units read directly from the scale of the instrument. Features include the choice of two sizes of bobbins, one for liquids of low viscosity (0–500 centipoises), and one for heavier liquids of 500 to 5000 centipoises. The stand incorporates a constant temperature bath which is readily placed and removed; also a ventilating fan to cool the magnetic coil above the bobbin. The 110-volt a-c. power supply is regulated to insure constant speed of the sample cup rotation and force applied to the bobbin.

Interchemical Dry Thickness Gage—Henry A. Gardner Laboratory, Inc., 4723 Elm St., Bethesda, Md. This gage with a suitable attachment can be used to measure foils or unattached sheet materials like paper, foils, etc., by the "feeler gage" method. A "visual" method is used to determine simply and accurately the thickness of attached coating such as paint materials on steel, etc. The instrument permits the measuring of coatings regardless of their hardness without deformation.

Corson-Cerveny Micro-Bellows Pump—Research Appliance Co., Box 413, West View Road, Pittsburgh 9, Pa. Primarily developed for laboratory scale pumping of materials which are liquid at room temperature but can be adapted to pump low boiling liquids such as pentane and melted solids (*e.g.*, naphthalene) and viscous materials. A pulsation type pump which delivers a constant rate over long periods of time. The rate is variable depending upon the size of bellows and position of the adjusting nut. This pump has the desirable feature of having no packing gland or stuffing box, eliminating all dangers of contamination of product by lubricants. The Type "C" Pump uses a stainless steel bellows which is electric welded to stainless steel fittings and attached to a stainless steel check assembly. All connections are machined fits requiring no compounds or gaskets.

INSTRUMENT COMPANY NEWS . . . .

Announcements, changes in personnel, new plants and locations, and other notes of interest

CONSOLIDATED Engineering Corp. has set up a new Department of Advertising and Public Relations. This new department will handle all advertising, sales promotion, and public relations for the firm, including national magazine advertising, catalogs, direct-mail campaigns, exhibits and trade shows, publicity and news releases, public relations program, technical manuals, and CEC Recordings. Philip S. Fogg, President, stated that under this new plan a smoother and more efficient program can be carried out for both divisions of the Sales Department, the Administration, and the company in general. George H. West has been appointed Director of Advertising and Public Relations to head this new department. Mr. West has been with Consolidated for seven and a half years and previously held the position of Advertising and Sales Promotion Manager under the Sales Department.

The C. J. Tagliabue Corporation (N. J.) was integrated into the operation of the parent corporation on January 1, 1950. As a consequence of integration Tagliabue apparatus will be made and sold by Weston Electrical Instrument Corp. in the future. The new name of this c pany will be Tagliabue Instruments I Weston Electrical Instrument Corp.

Calendar of Society Meetings

AMERICAN ELECTROPLATER'S SOCIETY—3 Annual Convention and Fourth In national Conference on Electrodeposit June 12–15, Hotel Statler, Boston, Mas

American Society for Testing Materia 53rd Annual Meeting and 9th Exhibi Testing Apparatus and Related Eq ment, June 26–30, Hotel Chalfo Haddon Hall, Atlantic City, N. J.

THE INSTITUTE OF PETROLEUM—Oil S and Cannel Coal Conference, July Glasgow, Scotland.

AMERICAN CHEMICAL SOCIETY—118th tional Meeting, September 3–8, Chic Ill.

INSTRUMENT SOCIETY OF AMERICA—Co ence and Exhibit, September 11 Buffalo Auditorium, Buffalo, N. Y.

NATIONAL PETROLEUM ASSOCIATION— tember 13–15, Hotel Traymore, Atla City, N. J.

INSTRUMENT SOCIETY OF AMERICA— National Instrument Conference and hibit, September 18–22, Memorial A torium, Buffalo, N. Y.

SOCIETY OF PLASTICS INDUSTRY—An National Conference, October 18–20, Ocean House, Swampscott, Mass.

AMERICAN SOCIETY FOR METALS—3 National Metal Congress and Exposit October 23–27, International Am theatre, Chicago, Ill.

NATIONAL FOUNDRY ASSOCIATION—An Meeting, November 8–10, Edgew Beach Hotel, Chicago, Ill.

AMERICAN PETROLEUM INSTITUTE—An Meeting, November 13–16, Biltmore Ambassador Hotels, Los Angeles, Cali

NATIONAL PAINT, VARNISH & LACQ ASSN.—November 15–18, Fairmont H San Francisco, Calif.

AMERICAN SOCIETY OF MECHANICAL E NEERS—Annual Meeting, November December 1, Hotel Statler, New Y N. Y.

AMERICAN INSTITUTE OF CHEMICAL E NEERS—Annual Meeting, December Columbus, Ohio.

High-Temperature Ceramics—M Summer Program

THROUGH its Division Ceramics, the Massachusetts Institut Technology Department of Metall will offer a two-weeks program in H Temperature Ceramic Materials, August 7 to 18, inclusive, as part of 1950 Summer Session. The program include a series of lectures on various t of high-temperature refractory mate particularly those important in com tion parts for guided missiles and in ponents of atomic energy reactors. L ratory experiments designed to fam ize students with modern equipmen fabricating and testing high-tempera refractories will be available.

For further details, write to Walte Gale, Room 3-107, Massachusetts I tute of Technology, Cambridge 39, M

The Design and Interpretation of Interlaboratory Test Programs[1]

by Grant Wernimont[2]

ONE important function of the American Society for Testing Materials is to develop test methods which are reliable when used in any testing laboratory. Many of these methods are quite complicated and require that a series of manipulations be carried out according to a specified procedure. A typical flow sheet is shown in Fig. 1, which gives the general method for determining five of the metallic constituents in a common alloy known as German silver and sets out. The method for copper is quite simple, while that for nickel requires almost a dozen consecutive steps.

It is necessary to work out the details of these test methods with care and then subject them to a collaborative study in several laboratories before they are officially adopted for A.S.T.M. use. The procedure for these interlaboratory studies is usually somewhat as follows: a homogeneous reservoir of test material is prepared and samples from the reservoir are tested in several laboratories according to the test method. The test results from the various laboratories are then assembled for study. Table I shows the results of a typical interlaboratory study of this kind in which nine laboratories determined the lead content of a National Bureau of Standards sample of steel.

An A.S.T.M. committee hopes to get information to answer the following types of questions from results such as these:

1. Does the method have any constant errors?
2. What limits of variation can be expected when the method is used by any single test operator?
3. What limits of variation can be expected when the method is used by any test operator in any testing laboratory?

It often turns out that no very satisfactory answers can be given to questions like these from the results which are obtained.

Figure 2 shows a control chart for the results in Table I. The control limits for ranges and averages have been computed by control chart methods in which the rational subgroups were the testing laboratories (see Appendix). The lower graph for ranges shows no evidence of a lack of control of the factors which cause variability within each laboratory. However, the laboratory averages

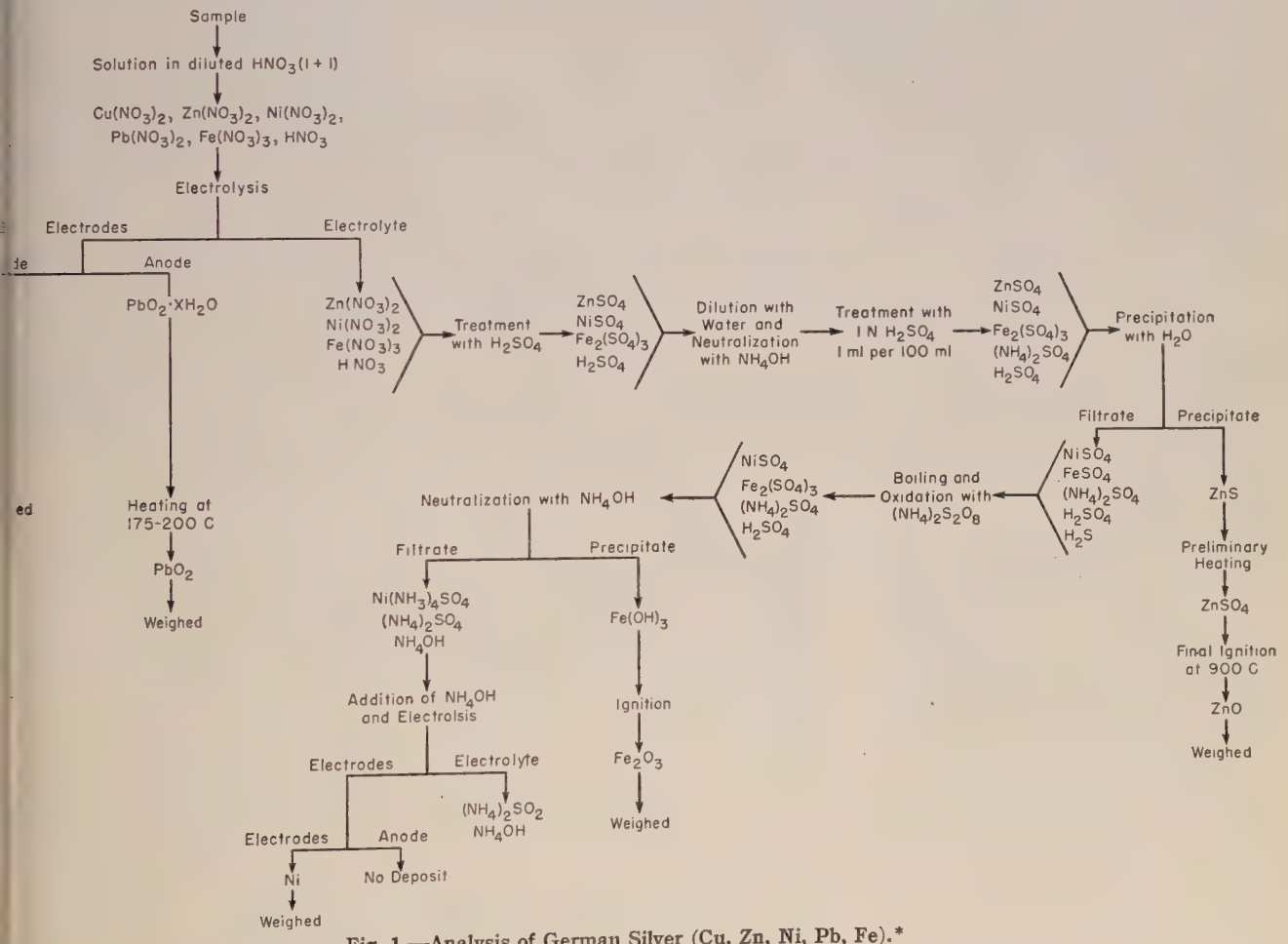

Fig. 1.—Analysis of German Silver (Cu, Zn, Ni, Pb, Fe).*

E.—DISCUSSION OF THIS PAPER IS TED, either for publication or for the tion of the author. Address all communica- to A.S.T.M. Headquarters, 1916 Race St., delphia 3, Pa.

resented before a Joint Meeting of the ican Society for Testing Materials and the ican Statistical Association, December 28, New York, N. Y.

astman Kodak Company, Rochester, N. Y.; ber of Committee E-11 on Quality Control of rials.

undell and Hoffman, "Outlines of Methods emical Analysis," John Wiley and Sons, New . N. Y., Table 105, p. 20p.

TABLE I.—LEAD CONTENT OF BUREAU OF STANDARDS SAMPLE NO. 130 CONTAINING 0.204 PER CENT LEAD.

Laboratory	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9
Determination A	0.211	0.197	0.200	0.202	0.207	0.189	0.191	0.206	0.202
Determination B	0.210	0.200	0.200	0.198	0.208	0.192	0.194	0.206	0.202
Determination C	...	0.196	0.178	0.211	0.208	0.195	0.191		0.189
Determination D	...	0.195	...	0.203	0.208	0.204			
Determination E	...	0.192	...	0.215					
Determination F	...	0.196							
Determination G	...	0.194							
Avg.[a]	0.210	0.196	0.193	0.206	0.208	0.195	0.192	0.206	0.198

[a] Grand average = 0.200.

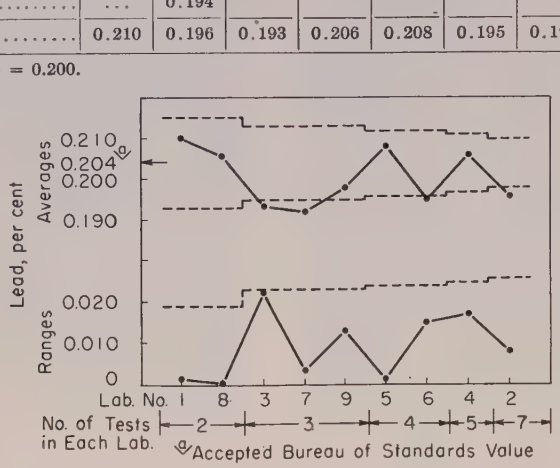

Fig. 2.—Control Chart for Lead Content of Sample No. 130.

(upper graph) fluctuate more than can be explained by the variability observed within the laboratory; and four of the laboratories are out of control on the low side. This seems to point to a rather unsatisfactory test method.

From a technical point of view, however, we need to know more about the "raw" data before we condemn or approve the method. Are the tabulated values of these data individual test results or are they averages? Were the results obtained by a single test operator in each laboratory? Were the test results obtained on the same day or on several days? Without information about such details, it is not possible to make a logical interpretation of the results of an interlaboratory study no matter how much statistical treatment is given to the data. The A.S.T.M. committees are beginning to be aware of this, and they want to design their interlaboratory test programs so that meaningful conclusions can be drawn from the results of their studies.

A.S.T.M. Committee E-11 on Statistical Quality Control of Materials has set up a Task Group to prepare a report on "Planning an Interlaboratory Study of a Test Method." The preliminary draft of the report is divided into five parts as follows:

I. Preliminary Survey of Existing Data.
II. Preparation of a Master Plan.
III. Operation of the Master Plan.
IV. Interpretation of the Results.
V. Publication of the Results.

In Part I it is recommended that simple control chart methods be used to get as much information as possible from existing test method data regarding:

(*a*) The fitness of the method for the types of materials it is designed to test.

(*b*) The precision and the constant errors which might be expected when the method is used.

(*c*) The kinds of assignable causes of error against which precautions need to be taken in setting up the test program.

(*d*) Preliminary estimates of stand deviations associated with following:

1. Tests made within very sh periods of time by a sin test operator under es tially the same conditions
2. Tests made from day to day a single operator under es tially the same condition
3. Tests made by different o ators using different set laboratory equipment.
4. Tests grouped in any other tional and hence compar way.

If a study of the existing data indic that some apparent contradictions h been observed in the behavior of the method, it is recommended that s able experiments be designed and ried out in some one laboratory in or to answer the questions raised.

In Part II of the procedure, an tempt is made to draw up an experim tal design for the interlaboratory program which will yield a maxim

TABLE II.—STANDARDIZATION OF SODIUM THIOSULFATE SOLUTIONS.
Values tabulated = (observed equivalents per liter − 0.1240)10,000

Laboratory	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	N
1 Day	11	7	9	10	9	13	11	4	12	15	
	10	11	13	10	9	11	11	4	11	15	
	11	6	11	11	9	10	7	9	11	15	
Avg.	10.7	8.0	11.0	10.3	9.0	11.3	9.7	5.7	11.3	15.0	
2 Days	9	12	11	10	9	8	9	10	10	11	
	9	12	11	10	9	9	13	7	12	11	
	8	9	11	10	8	7	12	9	12	13	
Avg.	8.7	11.0	11.0	10.0	8.3	8.0	11.3	8.7	11.3	11.7	
3 Days	9	11	11	10	10	9	9	5	13	13	
	6	9	11	10	10	8	9	10	11	10	
	11	10	10	10	11	9	10	10	12	11	
Avg.	8.7	10.0	10.7	10.0	10.3	8.7	9.3	8.3	12.0	11.3	
Lab. avg.[a]	9.3	9.7	10.9	10.1	9.3	9.3	10.1	7.6	11.6	12.7	

[a] Grand average = 10.0.

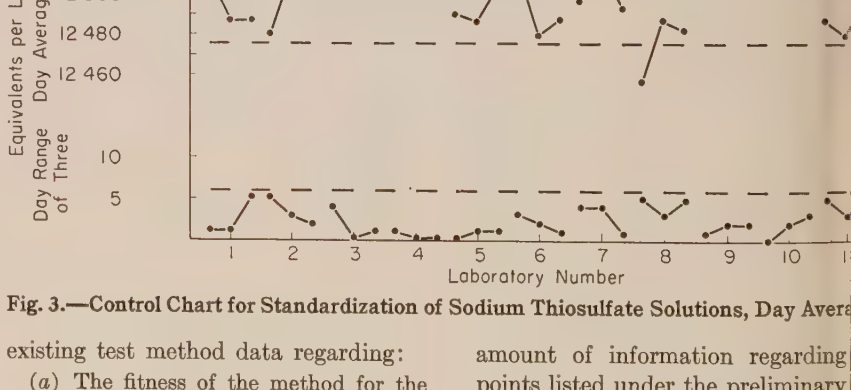

Fig. 3.—Control Chart for Standardization of Sodium Thiosulfate Solutions, Day Avera

amount of information regarding points listed under the preliminary vey. It is recommended that at two reference materials be prepared use throughout the test program. T materials should represent the extr of the types of materials which method is designed to test. Rathe tailed methods are given on how ran samples of the materials should

BLE III.—ANALYSIS OF VARIANCE,[a] STANDARDIZATION OF SODIUM THIOSULFATE SOLUTIONS.

Source of Variation	Degrees of Freedom[b]	Sum of Squares	Mean Square	F Ratio[c]
Among laboratories	(11 − 1) = 10	170.7	17.07	3.9[d]
Among days within laboratories	11(3 − 1) = 22	100.7	4.58	1.8[e]
Within days	33(3 − 1) = 66	165.3	2.50	...
Total	98			

[a] Computed from values taken from Table II.
[b] The number of deviations minus the number of constants determined from the experiment and used fix the points from which these deviations were measured.
[c] Ratio of mean squares which can be compared with theoretical values that will be exceeded only when nificant components of variance exist.
[d] Significant at 1 per cent probability level.
[e] Significant at 5 per cent probability level.

ected for distribution to the various boratories. It is emphasized that the d and number of replications used roughout the entire study should be iform so that comparisons of vari- ility within and among laboratories n be made more easily.

The results of an interlaboratory dy which follows the design of the commended procedure are shown in ble II. In this study, a proposed thod of standardizing a commonly ed chemical reagent was examined. andardization tests using the method re carried out on three different days ring a period of one week in each of ven different laboratories. A single t operator performed the tests in each oratory, and three individual tests re made on each day. It is not pos- le to study the constant errors of this t method because the standard values the solutions tested were not known ctly. The variability within days, ong days within laboratories, and ong laboratories can be studied.

Part III of the recommended proce- re suggests that the master plan be jected to a pilot run with only a few oratories collaborating. At this int, some final changes in the design the program and in the test method lf can be made if this seems desirable.

Part IV, which deals with the in- pretation of the results of the study, been one of the hardest to draft be- se it is felt that the exact course to followed often depends a great deal the nature of the results themselves. preliminary control chart is recom- nded. Other statistical methods such analysis of variance may also be used his seems desirable.

to find and remove the assignable causes of small day-to-day variability within a laboratory so long as it is not erratic.

The control chart for laboratory averages in Fig. 4 has limits based on (1) the variability within days and (2) the variability within laboratories (see Appendix). It seems quite clear that laboratories cannot be expected to agree with each other within limits based on the variability within days. Laboratories Nos. 8 and 10 approach the limits based on total variability within laboratories, and it would be worthwhile to try to find a reason for this.

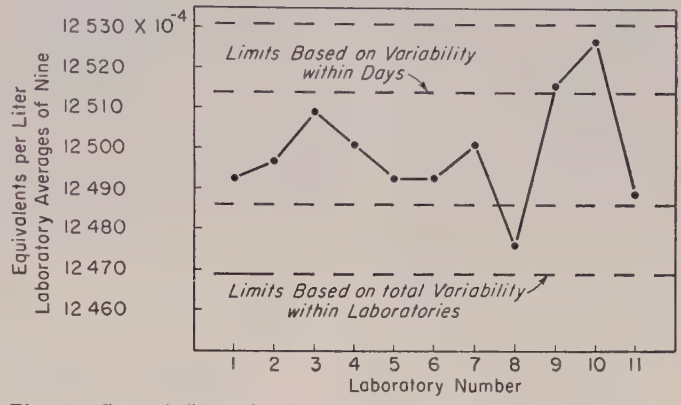

Fig. 4.—Control Chart for Standardization of Sodium Thiosulfate Solutions, Laboratory Averages.

A control chart for the thiosulfate standardizations is shown in Fig. 3. The control limits for test operator ranges and averages are based on the average range of three standardizations made by an operator on the same day (see Appendix). The lower graph for ranges shows no evidence for serious lack of control of the factors which contribute to the variability of repeated standardizations made on the same day.

The upper graph for day averages shows evidence of lack of control of some of the factors which cause variability from day to day in the eleven laboratories. The variance analysis for these results (Table III) indicates that a large part of this variability is among the laboratories, although the day-to-day variability within the laboratories should not be ignored. This kind of behavior is often observed in the results of tests like this. Usually it is not possible, from an economic point of view,

The concluding part of the recommended procedure gives some suggestions about publishing the results of the interlaboratory study. It is recommended that the report include all of the original data unless it is very large. Tabular summaries should be drawn up if they make it easier to interpret the results. It is suggested that control charts should always be used when this is possible, and great care should be taken to explain fully the methods used to compute control limits.

Up to the present time, very few A.S.T.M. committees have followed a procedure such as this in conducting their interlaboratory studies. There is no question that a great deal more useful information will be obtained from a collaborative test program when a procedure of this type is followed.

APPENDIX

Summary of Calculations for Control Limits[a]

Interlaboratory Study of Determination of Lead in Steel:

From Table I,

$\bar{Y}' = 0.204$ per cent lead

σ' = average value of ratio $\frac{\text{observed } R}{d_2}$ for individual laboratories

$$= \frac{1}{9}\left[\frac{0.001}{1.128} + \frac{0.038}{1.693} + \frac{0.016}{2.059} + \frac{0.017}{2.326} + \frac{0.008}{2.704}\right]$$

$= 0.005$ per cent lead

Control Limits for Ranges

$\bar{R} = d_2\sigma'$; Limits = $D_1\sigma'$ to $D_2\sigma'$

Sample Size...	2	3	4	5	7
Upper Control Limit	0.019	0.023	0.024	0.025	0.026
$\bar{R}$	0.0056	0.0085	0.0103	0.0116	0.0135
Lower Control Limit	0	0	0	0	0

[a] For a more complete description of these niques see A.S.T.M. Manual on Presentation Data, Am. Soc. Testing Mats., pp. 49 and 50 ued as separate publication, *STP No. 15-B*); A. Brownlee, "Industrial Experimentation," emical Publishing Co., Inc., Brooklyn, N. Y., 49–52 (1948).

Control Limits for Averages
Limits $= \bar{\bar{X}}' \pm A\sigma'$

Sample Size...	2	3	4	5	7
Upper Control Limit.....	0.215	0.213	0.212	0.211	0.210
Lower Control Limit.....	0.204	0.204	0.204	0.204	0.204
Avg.....	0.193	0.195	0.196	0.197	0.198

2. Interlaboratory Study of Iodine Method for Standardization of Sodium Thiosulfate solutions:

From Table II,

$$\bar{\bar{X}} = \frac{\text{grand average}}{10{,}000} + 0.1240 = 0.12500 \text{ equivalents per liter}$$

$$\sigma' = \frac{\bar{R}}{d_2} = \frac{0.0077}{33 \times 1.693} = 1.38 \times 10^{-4} \text{ equivalents per liter}$$

Control Limits for Ranges of Three Tests Made on the Same Day

Limits $= 0$ to $D_2\sigma' = 0$ to $(4.358 \times 1.38 \times 10^{-4})$
$= 0$ to 6.0×10^{-4} equivalents per liter

Control Limits for Averages of Three Tests Made on the Same Day

Limits $= \bar{\bar{X}} \pm A\sigma' = 0.12500 \pm (1.732 \times 1.38 \times 10^{-4})$
$= 0.12476$ to 0.12524 equivalents per liter

Control Limits for Averages of Nine Tests Made on the Same Day

Limits $= \bar{\bar{X}} \pm A\sigma' = 0.12500 \pm (1.000 \times 1.38 \times 10^{-4})$
$= 0.12486$ to 0.12514 equivalents per liter

Control Limits for Averages of Nine Tests Made in One Laboratory with Three Individual Tests Made on Each of Three Different Days

Let S_{WD} = estimated standard deviation within days
S_{AD} = estimated standard deviation among days
S_L = estimated standard deviation of laboratory averages (3 individual tests made on each of 3 days)

Using mean square values from Table III,

$$S_{WD}^2 + 3S_{AD}^2 = 4.58 \times 10^{-8}$$
$$S_{WD}^2 = 2.50 \times 10^{-8}$$
$$S_{AD}^2 = \frac{4.58 - 2.50}{3} \times 10^{-8} = 0.69 \times 10^{-8}$$

$$\text{Limits} = \bar{\bar{X}} \pm 3S_L = \bar{\bar{X}} \pm 3\left[\frac{S_{WD}^2}{3} + \frac{S_{AD}^2}{3}\right]^{1/2} = 0.12500 \pm (3.1 \times 10^{-4})$$
$= 0.12469$ to 0.12531 equivalents per lite

List of Symbols

X = variable magnitude in a series o observations;

R = the range, the difference betwee the largest and smallest ob served values in a sample o group;

$\bar{X}$, $\bar{R}$ = the bar ($^-$) notation is used t signify the mean or averag value of a set of X values or values;

$\bar{X}'$, σ' = the prime ($'$) notation is use to signify the objective or stand ard value of average and stand ard deviation as distinct fro the observed sample values;

$\bar{\bar{X}}$ = the grand average of a group sample averages;

d_2 = a constant, which varies with that relates σ' to $\bar{R}$ of the distr bution of R for samples of n ob servations each; that is, $\bar{R}$ $d_2\sigma'$;

A, D_1, D_2 = constants, from Table I, 50 of A.S.T.M. Manual on Pre entation of Data, which are use to compute 3σ control limits f averages and ranges of sampl of size n.

Comparative Tests in a Single Laboratory[1]

By W. J. Youden[2]

Synopsis

It is a fact of experience that a set of measurements made by different operators, at different times or in different localities is subject to greater variation than a set of measurements made by one operator using the same apparatus on the same day. The data from an experiment with thermometers have been used to show that even as simple an operation as reading a linear scale cannot be duplicated nearly as well after a time lapse as on the same day. The paper emphasizes the necessity of including in the error of the test all sources of variation which in fact operate on the measurements and shows how a change in the design of the test may reduce the error.

To say that two or more test results are in accord is to say that the observed differences among the test results are in keeping with the recognized errors of measurement associated with the test procedure. The problem, therefore, becomes one of discovering for each test procedure its appropriate error. It is just here that much confusion arises. Experimental studies of a test procedure often show that two results by different operators on the same material do not agree as well as duplicate results by either operator. Similarly tests on different days by the same operator do not agree as well as his results on any one day. There is much talk about operator effects, day-to-day effects, and laboratory effects (for interlaboratory tests). Statistical techniques are brought into the picture to isolate the various "components of error," and these soberly confirm that, for the same material, a collection of test results from several laboratories is more dispersed than a similar set from a single laboratory. This is not to deny the usefulness of statistical analysis as a means of appraising quantitatively the various contributions to the error that arise from operator, equipment, time, and locality. Statistics can locate and appraise sources of error; they cannot remove them. Some people may ha been led to expect that elaborate st tistical calculations will remove err from the test results. This will happ only if, as a result of the statistical a alysis of experimental results, the te procedure is modified and improved.

Precision of Comparative Tests

What is the appropriate error for test procedure? The answer is given b an important principle which will recognized by every experimentali This principle states that in appraisi an observed difference in test results two different materials the appropria error is found by comparing tests homogeneous material *tested under same diversity and extremes of testi conditions* that were involved in obtai ing the test results on the materi under comparison. There is no way get around this principle. It is a func mental precept in the proper interp tation of test results. This is the re son it is often arranged, for unusua important comparisons, that all the te are conducted by one operator using possible, the same equipment on t same day. It is a fact of experien that this enhances the precision of comparison. In the face of this exp ence it is unreasonable to expect tha

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Presented at a joint meeting of the American Society for Testing Materials and the American Statistical Association, New York, N.Y., December 28, 1949.

[2] National Bureau of Standards, Washington, D. C.

TABLE I.—DIFFERENCE BETWEEN DUPLICATE READINGS OF CLINICAL THERMOMETERS (READER A).

Difference, deg.[a]	Frequency	Per cent
0.00.....	254	39.2
0.01.....	218	33.6
0.02.....	119	18.4
0.03.....	31	4.8
0.04.....	17	2.6
0.05.....	7	1.1
0.06.....	2	0.3
Total	648	100.0

[a] Average difference in readings, 0.0102 F.

will be possible to specify a test procedure in such minute detail that the results from different laboratories or even from the same operator at different times will have as small an error as results from the same operator on the same day.

Naturally it is desirable to explore the situation. Perhaps controlling the temperature and humidity, screening the operators, and more exact specification of the way the test is conducted, will reduce the dispersion of the results obtained. There is a limiting goal and it will rarely be reached because it is so difficult to maintain or reproduce at different places and times the same environmental conditions, reagents, equipment, and operators. All these factors are briefly constant for a given place and time, and so two tests conducted close together are subject to the same *influences* and the difference between the tests is immune to many of the sources of errors which plague comparisons of tests from different operators or laboratories.

It is not hard to find examples to illustrate the point that there is no one experimental error which applies in all the conditions under which a test method may be used. Consider the calorimetric determination of the heat of solution of a cement. A mix is prepared from a cement and several test specimens poured into vials. At intervals, usually one and three weeks, calorimetric determinations are made upon the cement specimens. In judging whether two cements have different heats of solution it is obvious that a mix has to be prepared for each cement. It is patently unfair to use, as a yardstick to judge any observed difference between two cements, the agreement found between duplicate vials of the same mix. The agreement between

TABLE II.—COMPARISON OF THERMOMETER READINGS[a] BY READERS A AND B, MARCH 3.

Holder	1st set		2nd set		3rd set	
	A	B	A	B	A	B
1.....	0.048	0.023	0.072	0.044	0.046	0.030
2.....	0.093	0.044	0.044	0.032	0.061	0.032
3.....	0.041	0.016	0.072	0.037	0.024	0.011
4.....	0.084	0.040	0.047	0.023	0.060	0.041

[a] Deg. Fahr. above 106.

different mixes prepared from the same cement must be used. Say what you like about specifying the conditions of mixing, it seems unreasonable to expect two vials from different mixes to be as much alike as two vials poured from one mix. On the other hand, a study of the effect of time on the heat of solution can be carried out using just one mix, and therefore errors arising from the difficulties in reproducing the mix do not enter into such comparisons.

It is generally recognized that good test methods are characterized by the precise description of conditions and techniques which, by the exercise of due care, can be adequately reproduced by the testing agency. It may seem to some that a test method which fails to yield results from different laboratories (or at different times in the same laboratory) which are as accurately comparable as consecutive results by one test operator is, in some way, deficient; that what is really needed is more work on the test method and its description. There is no gainsaying that a great many test procedures would be improved with further study. On the other hand, as the next example will show, there is good reason to believe that even the most simple test procedure imaginable cannot be made immune from certain operator and time effects. In that event, whenever comparisons involve different operators and times these effects must be included in the error that is used to judge these comparisons.

Precision of Scale Readings

It is difficult to think of a practical test operation that is less complicated than reading a linear, uniformly divided scale. A clinical thermometer is an example. These thermometers have the advantage that, due to their construction, the mercury column remains in place. The reading of the thermometers is facilitated by mounting them in sets of 18 on a cylindrical holder which can be rotated to bring each thermometer under a magnifying glass. The operator reads each in turn, calling off the result to a recorder. After going once around the holder, a second circuit is made calling off a second reading for each thermometer. The scale divisions are two tenths of a degree and the readings are called off to hundredths of a degree, *i.e.*, to one twentieth of a division. As an indication of how expert these operators become, Table I shows that the average difference between the two readings for a thermometer is just about 0.01 degree. This is almost certainly a genuine skill since it is hardly likely that a given thermometer reading will be recalled after reading 17 others in between. In spite of this excellent agreement between readings taken within a few minutes, the following experiment shows that the agreement is much less satisfactory when the readings are taken over an interval of weeks.

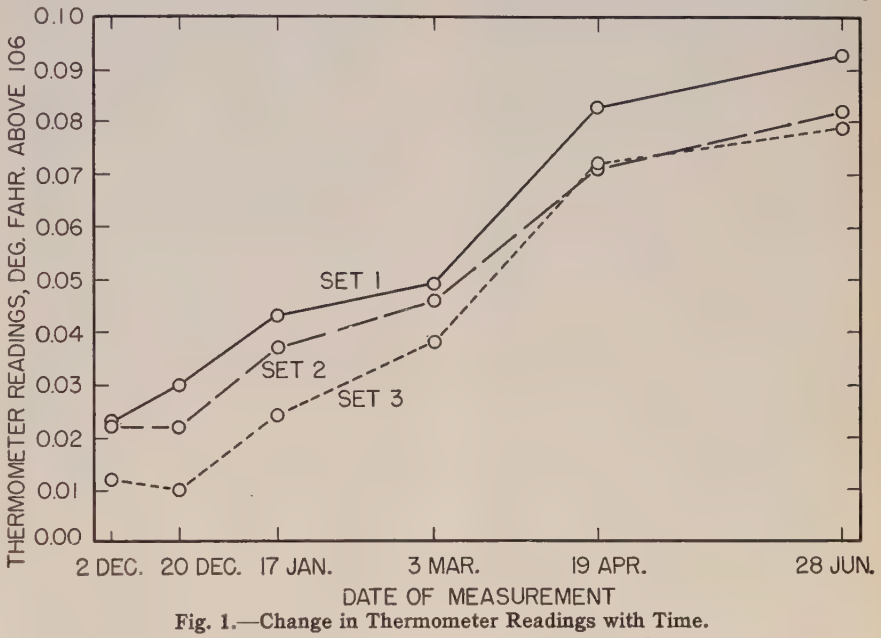

Fig. 1.—Change in Thermometer Readings with Time.

Average readings at six dates for each of three sets of 72 thermometers when immersed in a bath at 106 F. Two readers read every thermometer each time. The averages plotted include the readings by both readers. The three curves show closely parallel results for the three sets of 72 thermometers.

Comparative Test on Themometers

It is common practice to allow thermometers to age for several months before placing the scale upon the stems. This allows time for any volume changes to take place after fusion of the stem to the bulb. A method of aging was devised and it was the purpose of the experiment to engrave the thermometers immediately after the aging treatment

and then take readings over a period of several months to determine whether the aging was successful. The full experiment was made on over a thousand thermometers divided among three styles of bulbs. Only one type will be considered in this discussion. Twelve holders were loaded, each with 18 thermometers which remained in the holders for the duration of the experiment. The testing bath accommodated four holders so that four holders (72 thermometers) were raised to the test temperature at the same time. The sets of holders were kept together so that three raises were necessary to raise all twelve holders. As soon as a set of four holders were raised to temperature all 72 thermometers were read twice (as described above) by the same reader. The thermometers were then shaken down, raised again, and read twice by another reader. The bath was brought to the test temperature each time as closely as could be determined by reading a standard thermometer. It is interesting that the *average* of the readings for the 72 thermometers should also show how closely the test temperature was repeated. This is true because, if single thermometers can be read to one hundredth of a degree, the average of 72 thermometers is known to a small fraction of a hundredth of a degree. Whenever the bath temperature is exactly reproduced the averages for the *same* 72 thermometers should agree to a fraction of a hundredth of a degree. The averages for the two raises for a given set of thermometers differed a good deal more than this. Due to the use of different readers it is at first impossible to tell whether this was due to a difference between readers or because the bath was not brought to the same temperature each time. (A third person was responsible for setting the bath temperature.) By observing the performance of all three sets at any one time (Table II) it was evident that one reader read consistently higher than the other. It is not tenable that, in setting the bath temperature, one reader always drew the high settings and the other the low settings. The initial readings were taken immediately after the thermometers had been engraved. The whole sequence of operations, using the same personnel and the same test temperatures, was repeated five times over an interval of six months. It was the purpose of the experiment to determine how much the readings of thermometers changed over this interval and to ascertain the accuracy with which this change is known.

Results of Tests

This is not the place to report in detail upon some of the interesting features of this experiment. The immediate concern is to examine the results. These are first shown in Fig. 1. The points plotted are the average values for each set of 72 thermometers at each time period. Each average rests upon 288 readings; 144 by each reader. Since the three sets of 72 thermometers were raised separately and each was maintained as a unit, the three sets might be considered as three separate experiments. True, the sets were not initially quite alike and differed slightly in their initial averages. This is of no consequence since it is the change that is to be measured and if the curves closely parallel each other it may be concluded that the sets confirm each other in the amount of change. This, indeed, appears to be the case, and the three increments over the total time period are in very good agreement.

Unfortunately the case is not nearly as good as it appears to be in this presentation of the data. There is another way of regarding the results. The three sets may be lumped together using the readings taken by just one of the readers. The readings taken by the other reader may be considered a second experiment. It is immaterial that the same thermometers were used, because a completely independent set of operations, that is, bath settings, were made for each reader. Since both readers used the same 216 thermometers, any discrepancy between the results obtained by the two readers cannot be due to different samples but must be ascribed to the testing and reading techniques. This point of view replaces the three curves for the three sets of 72 thermometers with two curves, one for each reader. The two curves refer to the same 216 thermometers so there can be no displacement due to different sets of thermometers. Differences between the curves must be charged to the test procedure.

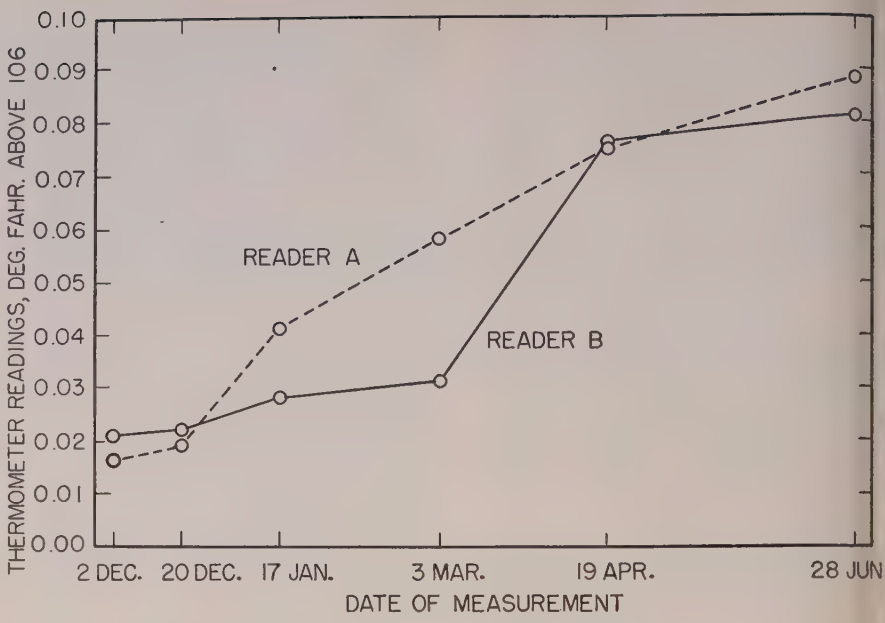

Fig. 2.—Change in Thermometer Readings with Time.

Average readings obtained by Reader A for 216 thermometers and for Reader B on the same thermometers. These are the same data used for Fig. 1. They have been regrouped to show the contrasts between readers at different dates.

The two curves are shown in Fig. 2. They create a very different impression from the three curves in Fig. 1. No longer are the curves parallel. Instead they cross and recross, and the change in the readings of the thermometers from the initial readings at the beginning of the experiment is obviously a good deal more uncertain. While the average of these two curves for readers will be identical with the average of the three curves for sets, it is plain that the average at each time is based on two points, one for each reader, that vary erratically by comparison with the three points for the three sets of 72 thermometers.

Interpretation of Test Results

No one looking at these two curves will feel as certain as before of the amount of change in these thermometers. Remember that the purpose of the experiment is to measure a change in reading over a long period of time. For this purpose the experiment is completely at the mercy of the ability of a reader to read the thermometers in the same way after a lapse of six months. This ability is entirely different from the skill displayed on a given day to read thermometers the same way. This latter skill is demonstrated, first, by the close concordance of the duplicate readings for each raise (the mercury does not change position in between readings) and, second, by the fact that on a given

ay one reader holds a bias over the ther reader (for all 12 holders) in spite f possible small differences in the bath emperatures. The only light thrown n the ability of a reader to read the ame after considerable intervals of ime is furnished by the six differences etween the averages for the two readrs—one difference for each of the six ates on which measurements were nade. These six differences will reveal whether or not there is a constant ias between readers. The curves (Fig.) show that, from time to time, the eaders reverse their relation to each ther. This could be accounted for by ssuming one reader to be unvarying in is bias and the other reader to be erratic. It is more plausible to regard both readers as varying in bias from time o time. Therefore the real change in he readings over the time interval is bscured chiefly because the bias for a eader may be different at the end of the ime interval from what it was at the eginning. The appropriate error for ppraising any observed change in the verages for two different times must ake account of this tendency of a reader o change. The statistical estimation f the error is made from the six differnces between the readers for the six vailable dates.

At this point it is pertinent to inquire why, on very much more complex operaions than reading a scale, one should expect to reduce the errors of comparisons involving different times and operators to that attained under the ideal conditions of within operator, within day comparisons. The contrast in the two accuracies will probably always remain in spite of much effort to reduce it. What is required, and what is too often ignored, is a clear facing of actual errors that exist in practical comparisons which of necessity usually involve errors attendant on the use of different operators or on the same operator at different times.

There may be some curiosity regarding the closely parallel curves for the three sets shown in Fig. 1. Recall that the points for each set are plotted from averages computed from the readings of both operators. Consequently each point is subject to the same influences and they move in unison. If it were of any interest, the experiment has managed thereby to establish differences between the averages for the three sets even though these are small by comparison with the indicated change in the thermometers over the six months. For the comparison of sets, the reader error associated with different times does not enter. The sets are compared on the same day and read by both readers so that any difference between readers is not involved. The accuracy of the comparison of sets is therefore very much greater than that of different times.

Improvement of Test Methods

This state of affairs suggests an alternative way of doing the experiment. If a supply of aged and stable thermometers is available, one of the holders in each raise should be loaded with these stable thermometers. To detect a change with time it is merely necessary to compare the test thermometers with the stable thermometers at each time. If it can be assumed that the aged thermometers do not change, then the change in the *difference* between aged and test thermometers over the time interval will reveal the change in the test thermometers. Not only will this device eliminate the reader-time contribution to error, but it is now unimportant to try to set the bath exactly for each raise. Aged and test thermometers share each raise and if the raise be high or low it does not matter, as the difference between aged and test thermometers is unaffected thereby. Thus another source of error will be eliminated from the experiment.

In any event it is indispensable to examine an experiment carefully and determine what sources of error are involved in the experimental contrast under consideration. A valid interpretation then depends on making sure that these same sources of error are included in the estimate used for appraising the experimental contrast. Figure 1 is definitely misleading because it conceals the error arising from varying reader bias. Errors computed from the triplicate points for each date would underestimate the real error appropriate for comparing readings taken at different dates. Figure 2 fairly represents the extent of information available for passing judgment upon the observed change in readings over the duration of the experiment. The duplicate readings at each date should be used to compute the error to be attached to the average for each date.

There are a number of statistical techniques coming more and more into use to assist the experimentalist in the isolation and evaluation of various components in the error of an experiment. No attempt has been made to expound these techniques. Of themselves they will not reduce the errors of an experimental comparison. These errors are, in the last analysis, reduced by the ingenious devising of experiments which take as their first principle the inclusion of means of estimating the real errors appropriate for the work in hand.

Discussion of Paper on Electrical Method for Evaluation of Protective Coatings as Moisture Barriers[1]

Mr. W. C. Ellis[2] (*by letter*).—We are using a testing method almost identical to that described by Mr. Arthur in work for the Air Materiel Command on tropicalization of communications equipment. Our objective is to find a coating that will "protect" the insulation-resistance properties of moisture-absorptive materials (for example, XX or XP grade bakelite) during several years of use or storage in tropical areas.

We are limited in our search to coatings which are comparatively transparent and which do not require an application temperature above 100 to 125 C. Therefore, Mr. Arthur's coating No. 4 (phenolic paint and lacquer, air dry) is extremely interesting to us, and we would appreciate more information about the composition of this coating, its manufacturer, etc. If his film-thickness measurement is correct (2.5 mils), this coating is far superior to any that we have yet tested. We presume that the data given in the article are for specimens exposed continuously to 99 per cent relative humidity, 95 F., and that those coated with No. 4 had an average insulation resistance of 16,000 megohms after five weeks of such exposure.

Mr. Arthur's data tend to support our contention that our problem cannot be completely solved except by use of comparatively thick coatings.

The type of testing method used by Mr. Arthur should become a valuable tool in the technology of protective coatings. It is generally agreed that many coating material failures are due to penetration of the films by moisture. This method provides an easy way to detect undesirable properties or tendencies in this direction. It should be emphasized that the procedure may be used as a way of evaluating the effects of all types of service conditions on protective coatings applied to many types of substrates. Usually, any serious deterioration of a film will be reflected by an increase in its over-all permeability to moisture.

The type of exposure test medium used is relatively unimportant. However, use of a highly humid atmosphere

[1] Marion A. Arthur, "Electrical Method for Evaluation of Protective Coatings as Moisture Barriers," ASTM Bulletin, No. 160, September, 1949, p. 57(TP155).

[2] Assistant Supervisor, Chemical Research, Battelle Memorial Institute, Columbus, Ohio.

(similar to Mr. Arthur's hotbox) will enable the results to be obtained most rapidly (within a few days, rather than 3 to 5 weeks). We would be inclined to distrust a procedure involving immersion, especially in a solution of an electrolyte, because of the possibility of occasional anomalous results due to surface conductivity, etc.

Our work has shown that, using a test similar to Mr. Arthur's, the rating of a coating material is a function of the moisture absorptivity of the substrate. If a relatively nonabsorptive substrate is used (for example, lucite or polystyrene, compared with XX or XP bakelite), most films will appear to be impermeable. This merely indicates that the body of the film does not provide a significant longitudinal path for electrical conductance.

We have also found that cycling of the exposure conditions, *per se*, does not seem to cause the permeability of a film to increase. However, the initial period of exposure to moisture does cause an increase that is not reversed, except by subsequent baking, etc.

It was interesting to note the correlation between moisture permeability of several films and the protection against rusting of black iron given by those same films. However, we would hesitate to conclude that moisture permeability is always the main factor involved in protection of a nonabsorptive, metallic substrate. A more thorough investigation of this matter would be valuable. Of course, this does not detract from the wide applicability of Mr. Arthur's electrical testing method.

Mr. M. A. Arthur (*author*).—Our coating No. 4, phenolic paint plus lacquer, is a single dipcoat of Rustban No. 270 followed by a single dipcoat of Roxyn 11C. The latter was originally made by Roxalin Flexible Finishes, Inc., Elizabeth, N. J. They have been taken over by Interchemical Corp. Rustban 270 is a product of Humble Oil and Refining Company. Its properties are as follows:

Color and finish	Flat reddish brown
Vehicle type	Phenolic resin-tung oil
Pigment	Zinc chromate
Solvent	Aromatic petroleum
Flash point	107
Weight per gal.	12.25 lb.
Stormer viscosity	24 sec.
Coverage	300 sq. ft. per gal.
Drying time	4 hr.
Thinner	Humble Thinner 680
Application	Spray or brush
Packages	1 gal. or 5 gal.

We use No. 270 regularly wherever the thicker wax coatings are objectionable, due either to thickness, heat resistance, or appearance. Roxyn lacquer is no longer in use here, principally because it offers very little protection alone. After 5 weeks, test strips coated with Roxyn 11C were down to 70 megohms. Incidentally, strips coated with No. 4 and No. 6 had resistances of 11,300 megohms and 3100 megohms, respectively, after 8 weeks.

These figures are all for the alternate immersion method, as were those in the published table. A brief comparison with data taken at 99 per cent relative humidity and 95 F. shows an acceleration of about 7 to 10 times as fast for these continuous high-humidity exposures.

When comparatively transparent coatings are specified, the field becomes very narrow. Roxyn 11C was one. Coating No. 9, or Rustban 670, is a clear varnish and we have used it on electrical parts not requiring unusual protection and where transparency was needed. There is a new clear electrical insulating compound now under test here, made by Minnesota Mining and Manufacturing Company, called Scotchweld 79 which requires a 2-hr. cure at 235 F.

Mr. E. G. Brink[3] (*by letter*).—More detailed information on this test procedure including, if possible, sketches of the electrical circuit and the method by which the lugs were mounted in the plastic specimens would be of interest.

The data published do not give a breakdown of the values obtained under the three sets of test conditions; and for the one-, two-, and three-coat systems.

What are the relationships between changes in resistances where equal film thicknesses are employed? This does not seem to be shown in the tabulation.

What method was used for determining whether or not there were any discontinuities in the films as originally applied?

The paper states that "the failure to protect is the all-important criterion in coating our metallic and electrical parts." It seems to us that in the tests conducted no consideration is given to the part that inhibitive pigments and adhesion play in the over-all protection afforded a metal surface.

Mr. Arthur.—I shall attempt to answer the points raised by Mr. Brink:

Electrical Circuit.—There are only two items involved—the test strip and the test meter. Resistance is read directly on the meter by clipping to the lugs on the strip. Our meter was the Megohm Bridge made by the General Radio Co., Cambridge, Mass. Other sources are Leeds & Northrup Co., Philadelphia, or the Shallcross Manufacturing Co., Collingdale, Pa.

Test Strip Connections.—These are silver-plated "turret lugs" used throughout many electronic devices. They are made by Cambridge Thermionic Co., Cambridge, Mass., and also by U. S. Engineering Co., Glendale, Calif. Each cylindrical lug runs completely through the test panel or strip and is fastened by rivet action on one end with a small flange at the other. The "turret" portion is part of the flanged end and stands out from the test strip a distance of $\frac{3}{8}$ in. The usual diameters are $\frac{1}{16}$ in. and $\frac{1}{8}$ in.

Test Conditions.—Preliminary data taken to establish optimum test conditions were completed over three years ago, and this was done for only a few of the more than thirty-five coatings tested. It was soon evident that a simple repeatable system was to use total immersion in 5 per cent NaCl solution with only one coat applied. Still available from rather voluminous data are some resistance figures ($\times 10^9$ ohms):

Coating	Alternate immersion	Humidity Hot Box	Suspended Over Solution	Time, weeks
No. 17	3.1	0.17	...	1
No. 18	9.0	0.25	...	1
No. 10	92.0	...	6.3	1
No. 25	2.1	...	1.6	1

Number of Coats.—The resistance of the continuous coatings changed so uniformly with the number of coats that for our purposes of rating the various materials the one-coat readings were sufficient. For example (in ohms $\times 10^9$):

Coating	1 Coat	2 Coats	3 Coats	Time, weeks
No. 17	3.1	9.6	23.0	1
No. 18	9.0	19.3	28.0	1

As indicated in the section above, the thicker the material the better it is as a water barrier. And, of course, our top two choices were over 20 mils. I do not know what the exact inhibitive mechanism might be within any pair of coatings of equal film thickness which give different resistances.

Discontinuities.—Two checks were available for disclosing discontinuities, which were numerous in some of the low-ranked coatings. First, three or more identical strips were always run, and if any strip differed from the others by more than three to one it was suspected. Second, an uncoated control strip (No. 16) was always in use and all suspicious cases within one to two additional weeks approached the resistance of the control strip.

Pigments and Adhesion.—Since we were looking for dipcoats only for use as water barriers, we made no direct tests of pigments or adhesion at the time. However, later on we did make an "edge leakage" test for adhesion of the top two

[3] Corporation Engineering Testing Dept. American Viscose Corp., Marcus Hook, Pa.

patings. The coated test strips were xposed to the salt solution 1 in. from ie turret lugs. This was far enough om the lugs so that moisture would not enetrate for several weeks through the akelite strip itself, but if there was poor dhesion between the coating and strip fast drop in resistance could be ex-ected. For these particular coatings ie adhesion was good.

As for pigments, their value can be own indirectly by the fact that the top iree of the so-called "thin" coatings, os. 4, 6, and 7 in the table, were all gmented.

Mr. C. Y. Hopkins[4] (*by letter*).—ur laboratories are at present develop-g tests for evaluating insulating var-shes. We should like to try this test id would appreciate further details of ie test method. The information that ould aid greatly concerns the design of the bakelite specimen, the method of applying the varnish, and the procedure in immersing the specimen in water and subsequent drying and testing.

Mr. Arthur.—The specific details asked for by Mr. Hopkins are as follows:

Design of Bakelite Specimen.—All test strips were of $\frac{1}{16}$-in. XX paper bakelite cut to 5 by $\frac{1}{2}$ in. A small notch was cut in one end for ease of hanging in test solutions. The other end was fitted with two pairs of silver-plated turret lugs. These pairs were 1 and 2 in., respectively, from the bottom end of each strip and the lugs of each pair were $\frac{5}{16}$ in. apart (or $\frac{3}{32}$ in. from each edge). The extra pair of lugs was useful as a double check or for special tests, but is no longer considered necessary.

Method of Application.—All coatings were dipped. Drying or baking was done according to each manufacturer's recommendations. It is important, however, that each strip be above 10^{12} ohms between lugs before coating. This can easily be done by drying all strips overnight at 150 F. before coating.

Immersion System.—It was found that several hours' drying after immersion was desirable in order to avoid interference by surface moisture. Our laboratory is kept between 50 and 60 per cent relative humidity which gives us a uniform drying rate. Twenty-four hours was found to be satisfactory for repeatability of results. Recommended practice, therefore, is now a 24-hr. immersion, a 24-hr. drying period, then a reading, for the first week. Thereafter, 1-week immersion, 24 hr. drying, then a weekly reading, should be sufficient. We have checked 32 coatings so far and found most of them well deteriorated in three weeks. All coatings were beginning to show porosity at eight weeks. The depth of immersion is not important. We found that lugs suspended $\frac{1}{16}$ in. above the NaCl solution showed coating deterioration as soon as those immersed.

[4] Protective Coatings Section, Division of Chemistry, National Research Council, Ottawa, Canada.

Fire-Resistant Finishes for Aircraft[1]

By J. A. Jones[2] and R. V. Niswander[2]

Synopsis

The occurrence of isolated fires in commercial, passenger-carrying aircraft has focused considerable attention upon the fire risks involved in the use of combustible materials, the arrangement of functional equipment and accessories, and the effectiveness of fireproof finishes and coatings. In addition to other studies concerning the elimination of fire hazard through careful survey of the electrical and other functional systems, studies have been made concerning the improvement of the ignition resistance of materials and the subsequent propagation of fire. Serious fires have developed as a result of propagation by materials which were not responsible for the original ignition of fire. An intensive effort has been made to reduce this fire hazard by the development and application of protective coatings and finishes to vulnerable and combustible materials. This work led to the obvious need for, and development of, a testing apparatus by which a realistic comparison could be made of combustible materials under conditions simulating those of an actual fire.

A refractory coating material has been developed which is considered to provide satisfactory fire protection for certain critical aircraft components. However, the excessive weight and difficulties incurred in its application indicate need for further development of materials which offer relatively complete fire protection. Paint type coatings have been produced which puff when subjected to heat and fire, and form an insulating foam. The protection afforded by these coatings under conditions of an actual fire is only marginal for aircraft applications. The test results indicate greater need for improvement in film characteristics than for improvement in fire protection.

A testing apparatus has been developed which was built to permit evaluation of combustible materials and fire-resistant coatings under conditions which approximate those incurred in an actual fire. The apparatus provides for the preheating of specimens at elevated temperatures before ignition, thereby, permitting more thorough study of conditions of fire damage.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] This paper was presented at the Session on Aircraft held at the First Pacific Area National Meeting of the Society, San Francisco, Calif., October 13-14, 1949.

[2] Lockheed Aircraft Corp., Burbank, Calif.

The postwar efforts of airframe manufacturers have been directed increasingly to the problem of producing commercial aircraft of increased safety Consideration of airplane safety from the standpoint of fireproofness has required continued evaluation of materials, equipment, arrangement of accessories and the protective finishes used in aircraft design. Commercial aircraft in contrast to military aircraft are designed for passenger comfort, utility, and appearance, and are equipped with materials and accessories that are inherently more susceptible to fire hazard. The occurrence of isolated aircraft fires and their subsequent propagation have emphasized the dangers associated with the use of more combustible materials. The aircraft industry, cooperating with Government agencies and airline operators, has made design modifications to reduce possible sources of aircraft fires, paying particular attention to operational failure of electrical systems and the arrangement of other equipment throughout the airplane. However, the total elimination of operational hazards is difficult, if not impossible, and the recognition of this fact requires that all materials be evaluated and screened as to their basic fire risk. This survey included not only structural materials but materials used to fulfill functional requirements, as well as those used for trim and furnishings. Several general approaches to the problem of reducing this hazard of fire have been made, including the elimination of excessively combustible materials where possible, the substitution

of materials having inherently better flame resistance, the protection of vulnerable as well as combustible materials with fire-resistant finishes, and the relocation of functional equipment to less hazardous areas. The purpose of this paper is a discussion of some phases of the work which have been directed toward the reduction of fire hazards with the use of fire-resistant finishes and coatings. We shall also discuss the development of a more realistic testing procedure for the evaluation of the flame-resistant properties of aircraft parts and materials.

Definitions and Test Procedures

The Civil Aeronautics Administration[3] has established the currently used definitions and test procedures governing the evaluation of materials from the standpoint of flammability. These definitions can be summarized as follows:

"Fireproof" materials or parts are defined as being capable of withstanding fire under most severe conditions. Materials are tested by exposure to a 2000 ± 50 F. flame for 15 min. No damage to the material or part is permitted.

"Fire-resistant" materials are defined as those materials which, although they may be damaged when exposed to flame, must perform their intended function. The test procedure requires application of flame for 30 sec., and any flaming of the material must cease within 15 sec. after removal of the flame source.

"Flame-resistant" materials are defined as those which will not support flame propagation beyond safe limits. Test samples are supported in a draft-free area in a horizontal position and exposed to direct flame. Materials are considered acceptable if they do not burn at a rate exceeding 4 in. per min.

Material that will pass flame-resistant, and even fire-resistant test requirements, will burn under conditions which are likely to occur in an actual fire. Interior trim and furnishing materials, which should fall under the category of "flame-resistant" materials, were subjected to more rigid tests than those specified for this category. The materials were flame tested in a vertical position rather than a horizontal position, and it was required that the flaming of the material should cease within 3 sec. after removal of the flame source. Although this work resulted in some reduction of fire hazard, we have recognized the need for more realistic test procedures to permit evaluation of materials under conditions that actually occur during a fire, and we believe that the development of such improved testing procedures will permit subsequent development of materials which are much improved in regard to flame resistance.

[3] Department of Commerce, Civil Aeronautics Administration, Safety Regulation Release No. 259, August 26, 1947 (in connection with the definition of the requirements for fire prevention of aircraft).

Development of Fireproof Coatings

Early recognition of the danger of a fire destroying such parts as oil tanks or ventilation ducts indicated necessity for the development of a coating to render these parts completely fireproof. It is desired that parts of this nature not be harmed in any way after exposure to direct fire for a period as long as 15 min. A coating fulfilling these requirements should be resistant to actual conditions of an airplane fire, to oil or water penetration, and to possible abrasion. Our initial work toward development of this type of coating included consideration of basic materials such as Buna N adhesive, paint inhibited with phosphate salts, ceramic adhesives, and refractory modified vinyl resins. The shortcomings of these materials included lack of adhesion, insufficient flexibility, tendency to absorb hydraulic oil, water solubility, and lack of aging stability.

The investigation indicated that the development of a refractory insulating shield material similar to putty was necessary. The characteristics of this putty should include resistance to flame temperatures of at least 2000 F. for 15 min. The material should also adhere to metals and wood at normal operating temperatures, should be noncombustible and noncorrosive, should resist oil absorption, should remain intact during combustion, and should remain stable and free from cracks under conditions of airplane vibration and operating air temperature variations. Several formulations for a putty of this nature were tested, and a plastic matrix that will cure by solvent release at room temperature in sections up to $\frac{3}{4}$ in. thick was finally developed. This putty material cures to form a hard yet not brittle insulating shield, has excellent thermal insulating characteristics, and will withstand a temperature of approximately 2000 F. Evaluation of the original formulation of this putty revealed loss in basic adhesion to metal at approximately 200 F., by partial decomposition of a vinyl resin incorporated as a binder. Subsequent requirements established the need for a binder that would retain the adhesion of the putty under higher operating temperatures. The vinyl resin was changed to a Buna N, binder which permitted higher operating temperatures before decomposition. This change permits the putty to adhere satisfactorily to metal up to 400 F. operating temperatures.

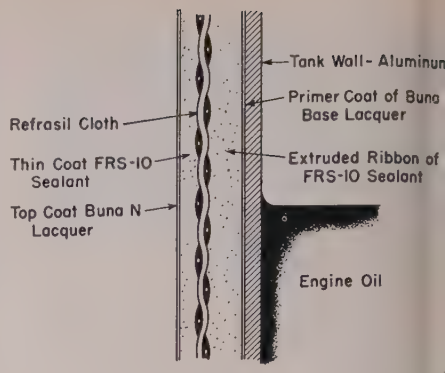

Fig. 1.—Cross-Section of Frs-10-RC Coating.

Inasmuch as this insulation putty loses its basic adhesion to metal at 400 F., an application procedure was needed to permit effective use of this material. The procedure developed for application of this material to aircraft structures is as follows: (1) Clean all surfaces with methyl ethyl ketone and thoroughly dry. (2) Apply a prime coat of Buna N base lacquer. (3) Apply putty approximately $\frac{1}{4}$ in. thick. (4) Wrap part completely with refrasil fiberglass cloth. (5) Apply a second coat of putty, using the base material thinned with methyl ethyl ketone. (6) Cure the part for 3 days to release all solvents. (7) Apply top coat of a Buna N lacquer. A cross-section of this coating is shown in Fig. 1. The formulation of this putty is designated *FRS-10*. The refrasil cloth is leeched fiberglass cloth and is used to bind the insulating putty to the part after the basic adhesion of the putty is lost by the release of the Buna N resin binder at temperatures above 400 F.

Actual fire tests were conducted on a partially filled oil tank to obtain complete evaluation of the fire prevention benefits. The object of these tests was to compare the fire risk involved in use of a partially filled oil tank without an putty insulation with a similar tank covered with various thicknesses of the putty insulation, when subjected to a 2000 F. fire for 15 min. These conditions would simulate an uncontrolled fire in flight. In either case, it was impossible to burn through the oil tank below the level of the oil. However, a hole was burned through the uncovered tank above the oil level in approximately $\frac{1}{2}$ min., and the center third of the tank was completely melted away after 15 min. flame exposure. A $\frac{1}{16}$ in. putty coating of the putty insulation was found to give marginal protection. Several places on the covered oil tank above the oil level were burned sufficiently after 15 min. exposure to 2000 F. flame to permit oil leakage when the tank was tilted. A uniform coating of putty $\frac{1}{4}$ in. thick completely protected the partially filled oil tank for more than 15 min. Figure

Fig. 2.—Appearance of Insulated Tank in Test Fixture Before Fire Test No. 1. Insulation Thickness 1/4 in., 18 gal. of 1120 Engine Oil at 80 F.

shows the appearance of the insulated ank in the test fixture before the fire est. Figure 3 shows the appearance of he tank after exposure to flame for 15 in. Note the sooty deposit on the il tank after the flame test, due to the ich flame mixture.

The fireproof coating just described s in current use as an insulating putty ealant for fire walls, hot air ducts, elec- ical junction boxes, as well as for oil anks. Because of the inherent dis- dvantages of this insulating putty, it is nprobable that any extended applica- on of this material will be made, not- ithstanding its excellent fire insulating haracteristics. These disadvantages bviously include excessive weight, com- lexity of application, and loss of adhe- on at elevated temperature. In view f these, it is apparent that continued evelopment is required to provide aterials suitable for the fire protection f vital components and critical struc- ires.

Evaluation of Fireproof Paints

For less critical applications such as ood or plywood flooring, partitions and entilation ducts, a material of lower eight than that described above is esired to reduce fire risk. Paint type oatings designed to "puff" and form an sulating shield were tested to evaluate e protection afforded to parts during a actual fire. A fireproof paint which rovides complete protection during re is required by the aircraft industry, contrast to fire-resistant paints as sed in other industries. Fire-resistant aints are designed only to limit the spread of the fire, and do not in themselves prevent combustion. The requirements for a fireproof paint for airplane usage on wood or plywood are: (1) Wood shall not be charred after exposure to a 2000 ± 50 F. flame. (2) The paint shall have good adhesion to the base material after exposure to water, hydraulic oil, and solvents. (3) The paint shall be flexible at low or high temperatures. (4) The paint shall resist vibration as might occur in flight or loading operations. (5) The paint coating shall have satisfactory aging characteristics.

Three proprietary paint formulations were tested for conformance to the above requirements. Since only two-part materials were available at the time of our test program, fire tests were conducted on this type.

The plywood panels used were 3/8-in., 5-ply plywood, 12 in. square. The panels were sealed with spar varnish prior to application of the fireproof paint. Two successive coatings were applied, allowing 48 hr. drying time between coats. A top coat of vinyl resin base lacquer was then applied over the fireproof paint to increase resistance to water and hydraulic oil. One inch strips of asbestos mill board were used to protect the edges of the panels during the fire test, thus precluding edge burning.

The three processed panels were exposed to a 2000 ± 50 F. flame for 15 min. The fire did not propagate along or through the painted surfaces. A similar uncoated panel ignited almost immediately upon exposure to flame and was charred through four of the five plies after 7½ min. of exposure. Figure 4 illustrates a three-quarter view of the test panels showing the end cross-section and the surface appearance after exposure to flame for 15 min. It is noted that the paint type coating puffed in all cases, forming an insulating blanket for the plywood panel. Figure 5 shows the cross-section of the same test panels at the center of the panel.

Fig. 3.—Appearance of Tank After Fire Test No. 1. Note Sooty Deposit on Tank Due to Rich Flame.

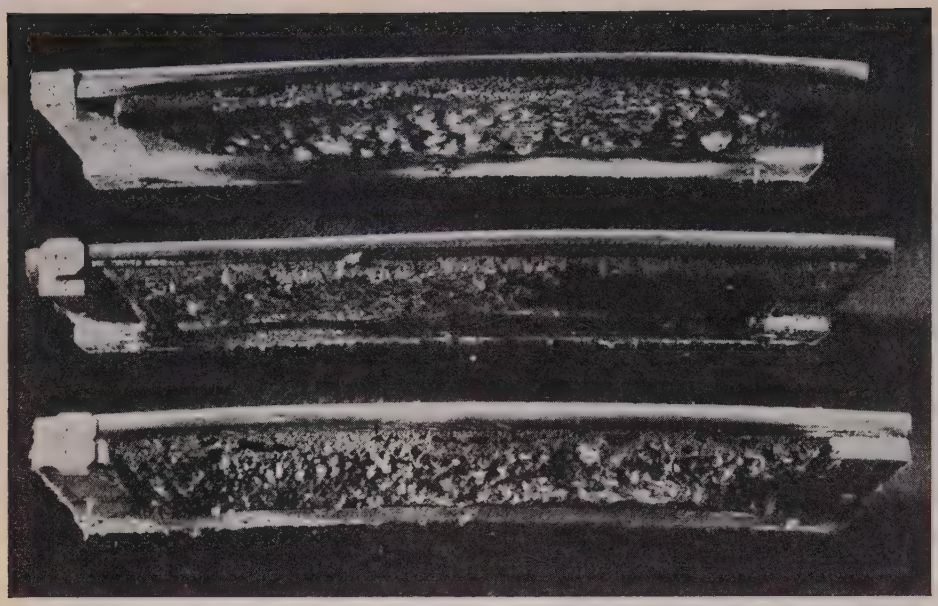

Fig. 4.—Three-quarter View of Fire Test Panels Showing Outer Cross-Section and Surfaces.
1. Manufacturer A. 2. Manufacturer B-Type 1 3. Manufacturer B-Type 2

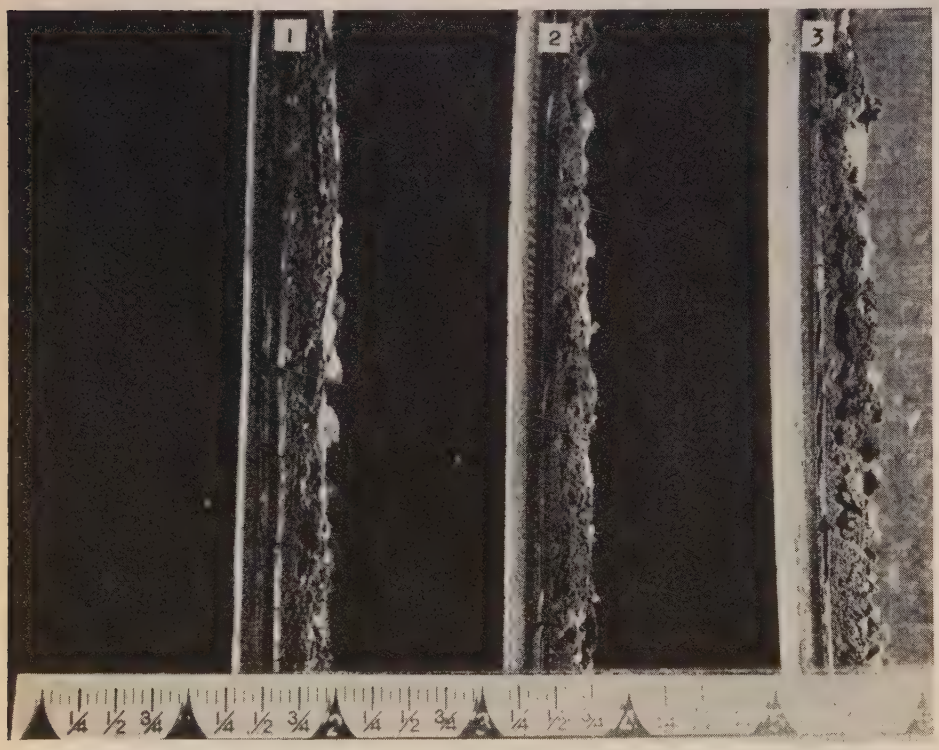

Fig. 5.—Cross-Section of the Center of Fire Test Panels After Exposure to 2000 F. Flame for 15 min.
1. Manufacturer A. 2. Manufacturer B-Type 1. 3. Manufacturer B-Type 2

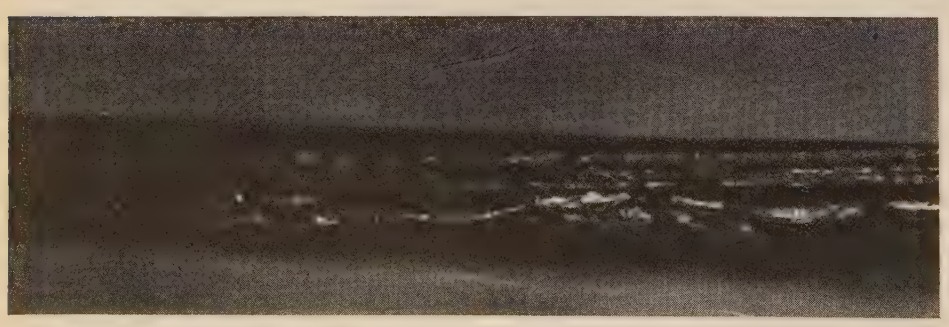

Fig. 6.—Cross-Section of the Center of the Unprocessed Control Panel After $7^1/_2$ min. Exposure to a 2000 F. Flame.

Panel one is charred through three plies and into the fourth ply. Panel two is charred through two and into the third ply. Panel three is charred through the first and into the second ply. Figure 6 illustrates the appearance of the unprocessed control panel after $7\frac{1}{2}$ min. exposure to the 2000 F. flame.

From the standpoint of fire protection afforded, this material was considered sufficiently acceptable to warrant an experimental application to the bottom side of the plywood floor boards installed in the airplane. Vibration tests were conducted on these floor boards at the frequency and amplitude of vibration occurring in flight. The floor boards were loaded to simulate movement of cargo or passengers in the airplane. Paint coatings applied to other floor boards were permitted to age for one month under normal conditions and the vibration tests were performed on these boards. Hairline cracks developed in the aged paint coating, although satisfactory results were indicated by vibration tests on the unaged coating. Loss of adhesion and poor aging characteristics were apparent for these particular formulations.

It is desired that this type of paint be modified to overcome these objections and also to provide greater resistance to water and hydraulic oil without need for additional top coating material. None of the formulations tested satisfied all the desired properties, but they do approach acceptable performance. All of the materials tested were prepared by mixing two products together to make a paint type coating. This type of preparation causes difficulty in insuring that the proper mix proportions are obtained. Consequently, it is desired that a one package material be developed for production applications.

Development of Elevated Temperature Testing Apparatus

Consideration has been given to the impregnation of fire-resistant compounds into some of the materials used for interior trim and fixtures during their manufacture. Although, in general, the present materials used conform to the current test requirements, as previous discussion has indicated the need for more restrictive test procedures for evaluation of the degree of flammability of these materials.

It was reasoned that materials in the immediate vicinity of a fire become superheated, and although normally flame-resistant, may be readily combustible when the temperature is raised a few hundred degrees. The development of the elevated temperature apparatus was pursued in an effort to explore the combustion characteristics of trim materials at elevated temperatures.

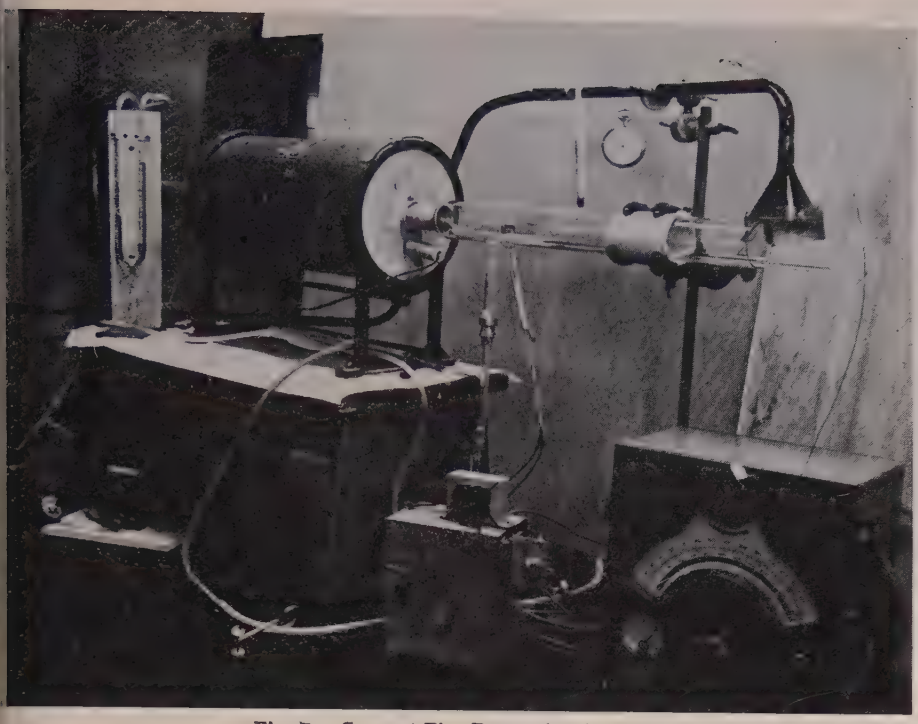

Fig. 7.—Current Fire Properties Apparatus.

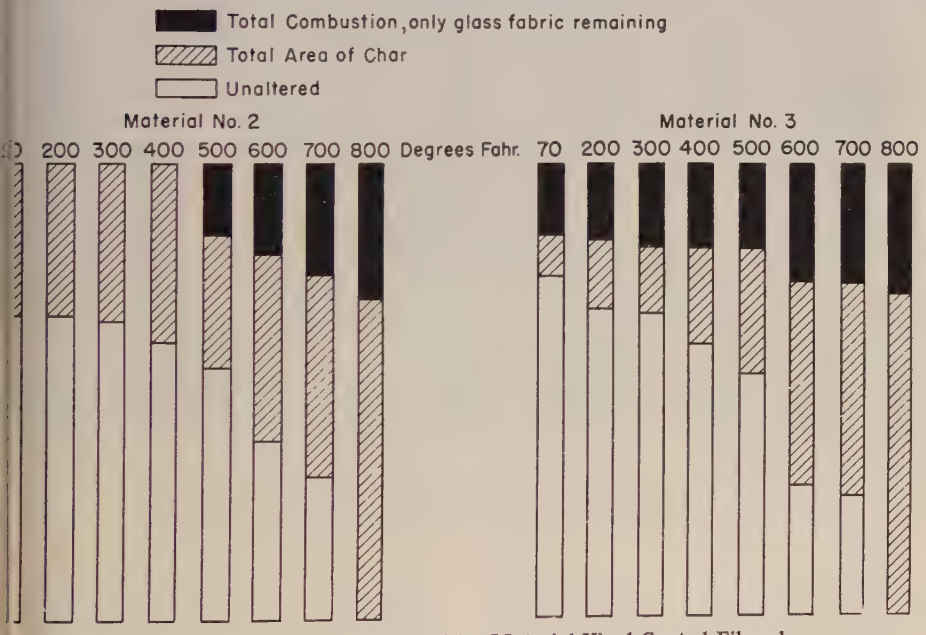
Total Combustion, only glass fabric remaining
Total Area of Char
Unaltered
Material No. 2
Material No. 3
200 300 400 500 600 700 800 Degrees Fahr.
70 200 300 400 500 600 700 800

Fig. 8.—Comparative Evaluation, Trim Material Vinyl Coated Fiberglas.

The test apparatus was designed to fill three basic needs inherent in attempting to evaluate the relative flame resistance of comparable trim materials at elevated temperatures. These conditions are: (1) A means of raising the temperature of the sample and the surrounding air to any desired point. (2) Instantaneous impingement of a flame upon the sample after a stabilizing period. (3) Visual observation of the results from the time the sample is introduced so that all possible effects can be noted, such as preliminary decomposition of sample prior to ignition, the effects of the ignition flame, and the burning characteristics of the materials tested. This third requisite was important inasmuch as all preliminary work was of an exploratory nature, and it was quite advantageous to observe the course of combustion at all times. The development of the apparatus served to give indications of those test conditions necessary to insure reproducible results.

It is felt that most of the above conditions have been met satisfactorily in our current test equipment. Figure 7 illustrates the test apparatus. A description of the apparatus may be of interest inasmuch as it can be used to evaluate the flame resistance of materials as well as the efficiency of fireproof or flame-resistant coatings. It consists essentially of a Pyrex combustion tube 43 mm. in inside diameter, with side arms for admitting a thermocouple, a burner for igniting the specimen and a spark arrangement for lighting the burner. Both specimen and tube are mounted in a horizontal position and heated by passing air at the desired temperature through the assembly. A convenient method of heating the air was accomplished by passing it first through a stainless steel tube inserted in a controlled combustion tube furnace and then directly into the combustion chamber. This method of heating has two distinct advantages. First, the equipment can be set in operation and good equilibrium can be established for a predetermined temperature prior to the introduction of the sample. Second, the constant flow of heated air prevents any accumulation of combustible gases resulting from preliminary decomposition of the sample prior to ignition. This continuous purging of the system not only serves as a safety factor but also insures an adequate and constant supply of fresh air for combustion of the sample.

The igniting burner was constructed of glass only because of expediency and is of the conventional air internal, gas external, jet type. It was designed to slip through one of the side arms and deliver a thin, pencil-like flame about 4 cm. long, at an angle of 30 deg. from the horizontal. In practice, it was found feasible to allow the air supply of the burner to remain on so that only manipulation of the gas and spark source is necessary for ignition of the burner at any instant. It is desired that the diameter of the flame be less than 1 cm. This feature is important from the standpoint of the evaluation of surface protective coatings in that "edge" effects are eliminated. Samples are cut to the full inside diameter of the combustion tube to preclude "edge" effects.

Other features have been incorporated in the assembly for the sake of convenience but are not essential for operation. These include a suction trap to remove smoke and toxic fumes at the open or exhaust end of the combustion chamber. A glass inner sleeve is included to reduce the need for dismantling the apparatus for cleaning. As the need for cleaning

25 sec. Flame at 100 F. | 20 sec. Flame at 150 F. | 20 sec. Flame at 200 F. | 15 sec. Flame at 300 F. | 10 sec. Flame at 400 F. | 5 sec. Flame at 500 F. | 5 sec. Flame at 860 F.

Fig. 9.—Results of Fire Tests on Previously Used Phenolic Resins.

Length of char was essentially the same, and above 500 F. no essential improvement was noted. It was concluded that while the basic fire risk was not essentially improved, the flame-retardant qualities and protection afforded by the fabric when installed adjacent to other more combustible materials was greatly improved, since these factors tend to localize a fire.

From the standpoint of test procedure, it is felt that while more elaborate and detailed than previous test methods, this new program gives a more general indication of all aspects of the protection afforded by a flame-resistant coating. The limits of protection from fire risk can be found, and, in addition, a more firm basis for material usage, with respect to fire risk, can be established in the design of airplane furnishings.

The limits of protection of a paper-surfaced plywood, 0.085 in. thick, were

arises, the sleeve is withdrawn and a new one inserted. It is believed, also, that this feature gives added insulation to the main tube, thereby insuring more constant temperature over the full length of the specimen. This inner sleeve also serves to reduce the thermal shock to the outside jacket. The temperature and heat of combustion of some materials has been so great that a few hours operation resulted in a broken jacket, prior to this improvement. Present plans call for a duplication of the described assembly constructed of Vycor glass.

The optimum velocity of air through the assembly had to be established and had to fill the requirements of heat transfer to the sample and removal of any combustible gases, as well as to insure results that were reproducible. A velocity of 0.6 mile per hour was found to fill the first two requirements and at the same time, variations of ±0.2 mile per hour did not significantly alter the results. The main source of variation, in most cases, has originated in the material or protective coating. Therefore, several determinations must be made at any given temperature level and ignition time. Repetition of tests at one temperature until a reliable result is obtained, plus data indicative of inherent flame resistance at temperatures varying in 50 to 100 F. intervals from that of the room temperature up to 860 F., gives a fairly complete analysis of the protection afforded by a surface treatment. It is felt that the following investigations of two widely divergent materials and means of protection serve to illustrate the latitude of this apparatus.

25 sec. Flame at 100 F. | 20 sec. Flame at 150 F. | 20 sec. Flame at 200 F. | 15 sec. Flame at 300 F. | 10 sec. Flame at 400 F. | 5 sec. Flame at 500 F. | 5 sec. Flame at 860 F.

Fig. 10.—Results of Fire Tests on Modified Melamine Resins.

The manufacturer of a coated fiberglass cloth voluntarily suggested a modified coating formula and submitted samples incorporating the changes. The accompanying bar graph, Fig. 8, illustrates the comparative results of the new material and that currently in use at temperature intervals of 100 F. up to and including 800 F.

It is obvious that at temperatures up to 500 F. the new coating material, No. 2, had improved resistance to contact with flame and protected the glass cloth from undue damage, whereas, the current coating material, No. 3, permitted damage to the glass cloth to the point of definitely weakening the fibers and over-all strength of the material.

investigated in a similar manner. While paper-surfaced plywood is not in the true sense a protective coating, the end results required and the methods of testing are quite similar. The paper-surfaced plywood is made by thoroughly impregnating the paper with a resin to bond the paper to the surface of the plywood. Previously, a phenolic resin has been used for this purpose. One supplier of this product was requested to modify his material by using a more fire-resistant resin such as melamine resin to bond the paper to the plywood. Figure 9 illustrates the results of fire tests on the previously used phenolic resin while Fig. 10 illustrates the results of fire tests on the modified melamine resin

Comparison of the two materials shows that at each temperature, the melamine resin protected the plywood far better than did the phenolic resin. At each temperature tested, the plywood was charred through the phenolic resin; however, the melamine resin protected the plywood when exposed to an igniting flame for the same period of time. In order to show that the melamine resin was vulnerable on prolonged exposure, the panels were tested for excessive periods of time. Three or four times as severe exposure on the melamine resin as those made on the phenolic resin was required to obtain the same degree of charring on the plywood. These tests show an indication of the additional protection afforded by the use of a more fire-resistant melamine resin in bonding the paper to the plywood. The conclusions, based on each series, are that the ability to resist ignition at temperatures up to 860 F. has been greatly increased by the use of the melamine resin.

In general, it is believed that the above examples using the elevated temperature testing apparatus verify the need for the more rigorous and comprehensive tests that can be obtained. In addition, the knowledge of the combustion tendencies at various elevated temperature levels will materially aid in design of airplanes.

Summary and Conclusions

This paper has discussed some of the phases of the work accomplished by the Lockheed Aircraft Corp. which was directed toward the reduction of aircraft fire hazards, through the use of fire-resistant finishes and improved fire testing procedures. Much of the experimental data presented are, of necessity, limited inasmuch as this work is still in the development stages and the information is of a restricted nature.

Subjects mentioned in this discussion represent only part of the over-all efforts being made by the aircraft industry to reduce the hazards of fire in aircraft design and manufacture. We wish to emphasize the need for continued effort on the part of the paint industry toward the development of fire-protective coatings and finishes in order to permit further reduction of fire hazard in commercial, passenger carrying airplanes.

Acknowledgment:

The authors wish to acknowledge use of information derived from research, development, and test work performed by the following members of the Lockheed Aircraft Corp. E. Simon and F. W. Thomas of the Chemical Research Group, for their work in the development of fireproof coatings; and F. P. Minnich also of the Chemical Research Group, for test work in connection with "puffing" type paint coatings. We are indebted to R. Della-Vedowa of the Mechanical Research Group, for his work in connection with the testing of the refractory insulating putty. We wish to acknowledge test work performed by C. T. Hamill and C. Mannheimer of the Chemical Control Laboratory, in connection with the initial evaluation of the "puffing" type paint coatings and the testing of coated fiberglass and paper-surfaced plywood specimens. The authors also wish to express their appreciation to H. B. Sipple for constant encouragement and aid in the preparation of this paper.

DISCUSSION

Mr. E. R. Hollinger[1] (*presented in written form*).—By way of enlargement on the section of the paper, presented by Messrs. Jones and Niswander, dealing with the evaluation of fireproof paints, it would probably be in order to review the improvements which have been realized in this type of coating since the tests already reviewed.

The paint type coatings now available are in the form of a liquid, one-package material which can be either sprayed or brushed, and the sensitivity of the dried fire-retardant coating to water has been materially decreased. When recoated with a suitable organic topcoat such as vinyl enamel, the resistance of water, hydraulic oil, and solvents is as satisfactory as most conventional type finishes. Present-day fire-resistant paint coatings are practically urea resin-free, which overcomes, to a very large degree, the undesirable qualities of embrittlement upon aging which were present in most of the coatings evaluated at the time the previously reported tests were made.

A brief résumé of the characteristics presented by the present-day one-package coating material would show the following characteristics. As mentioned, the material can be applied either by brush or spray, and two coats of the material should be applied to obtain the optimum film thickness for desirable fire-retardant characteristics. The weight of a film thus applied would approximate that of a conventional protective coatings paint film. The material is of a nature which puffs upon exposure to high temperatures, and under 15 min. exposure to a 2000 ± 50 F. flame will show no charring of the wood so protected. The insulating character of the puff is such that should the initial puff be removed by excessive vibration, etc., a secondary puff will immediately form which produces a bulk approximately 60 per cent of the original volume of puff which is also adequate to prevent charring for the same period of time under the same temperature flame. The puffing temperature of currently offered coatings of this nature is somewhere in the vicinity of 300 ± 50 F. Actually, slight puffing will take place for prolonged exposure to temperatures as low as 225 to 250 F.

One of the most important characteristics of the improved puffing type paint is in the physical nature of the puff which is formed. Instead of forming a dry, flaky, brittle ash, the puff is somewhat sticky in nature, which characteristic is particularly significant in the tendency of the puff to maintain its structure and adhesion to the treated surface under relatively severe vibration conditions. While the puff formed with the newer type coatings will resist considerably more vibration than the older coatings, this type material could in no way be applied to surfaces exposed to relatively high velocity movement of air such as would be encountered on the exterior surfaces of commercial aircraft or the inside of air intake ducts, etc.

For the less critical application such as wood or plywood flooring, partitioning, etc., it is felt that this type of coating offers possibilities for practical application. The new type coatings have greatly improved package stability over previous materials offered, show greatly improved adhesion to both wood and chromate primed metal surfaces, they exhibit greatly improved flexibility over the previous urea formaldehyde resin type of coating, and do not give off any appreciable amount of poisonous fumes when burned. When applied to metal test panels, aged one month and bent over a $1\frac{1}{2}$-in. mandrel, the newer type coatings show no appreciable tendency to crack or peel from the surface.

Air speeds equivalent to 50 mph. are sufficient to remove completely the puffed structure from the surface so that these materials should definitely be considered for use only in protected areas. We believe that for surfaces exposed to high air velocities will definitely have to be of the matrix type mentioned in the previous report.

Testing procedures for this type of finish, we believe, should include the 15-

[1] Technical Director, Los Angeles Laboratory, The Sherwin-Williams Co., Los Angeles, Calif.

min. test with a 2000 F. blast flame, a water soaking test for the completed system (fire-retardant paint plus protective topcoat), a mandrel bending test of possibly $\frac{1}{2}$-in. diameter bend after one week's aging at room temperature, and very definitely a weight per unit area required to form a given thickness of protective puff. The paint should also be evaluated from the consideration of the length of time on a standard vibration test as outlined in the previous paper, for complete removal of the puff. This vibration test should probably be performed on the puffed material alone and also on the puffed material during the application of the flame. We believe that the test procedures used for evaluating coatings of this type should simulate as nearly as possible the actual surface conditions to which they will be exposed. For example, if the coating is to be evaluated for fire protection on the under surface of plywood flooring, the test specimen should be supported in a horizontal position in a rack which will simulate operating strains and vibrations. The test flame should be applied from below normal to the under surface of the test specimen. If the coating is to be evaluated for protection to vertical partitions, the test specimen should be mounted in the stress vibration rack vertically and the test flame applied practically parallel to the coating surface.

Air Materiel Command[2] (*presented in written form*).—The experience of the Materials Laboratory of the Air Materiel Command in evaluating fire-resistant coatings has been limited to the intumescent or "puff" type as described in the paper. The results of tests closely paralleled those obtained by the Lockheed Aircraft Corp. which indicated that the presently available coatings of this type are not satisfactory for aircraft use due to their poor moisture resistance, flexibility, vibration resistance, and heat resistance. (The coatings began to decompose at temperatures between 250 and 300 F.) Several other type coatings have been received recently and evaluation of these materials will be initiated in the near future.

It is realized that fire-resistant coatings are not new and many of the materials brought to the attention of this Command which have been used successfully on items such as buildings, motors, machinery, and heating ducts are unsatisfactory for use on aircraft due to the severe and varied conditions to which the coatings are subjected. It is felt that fire-resistant finishes for use on aircraft must be tailor made, and manufacturers should keep in mind from the beginning the performance requirements which must be incorporated into the coating. Some of the more important properties are good humidity resistance, low temperature flexibility, resistance to fuels, oils, hydraulic fluids, vibration resistance, good adhesion and application properties on various metals and wood, and resistance to temperatures which may be high but normal operating conditions. In other words the material must have the durability and resistance properties of a good paint coating, yet incorporate the needed fire resistance properties.

The Air Materiel Command has not been sufficiently involved in the evaluation of these coatings to justify the development of any special test equipment. Evaluations have been limited to various resistance tests under operating conditions and fire resistance tests at a temperature of approximately 2000 F. This Command will continue to evaluate fire-resistant coatings as they are brought to its attention, but in view of the extensive investigations being conducted by N.A.C.A. and other aircraft agencies it is not contemplated that a full-scale development program will be initiated in the near future. However, any interested agency is invited to submit to the Air Materiel Command for evaluation, samples of fire-resistant coatings which have shown by previous tests to have merit.

Mr. E. T. Nelson.[3]—Have the authors noticed any effort on the part of manufacturers to reduce the amount of shrinkage of the material when exposed to heat? Our tests show that some materials are inclined to shrink away from the edges when heat is applied.

Mr. J. A. Jones (*author*).—The samples used for testing "puffing" paint type coatings were protected with asbestos to prevent edge burning during fire testing. Inasmuch as the usage of this type of material was contemplated for continuous surfaces, the shrinkage of the coating was not observed.

[2] Dayton, Ohio.

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Fatigue Characteristics of Aircraft Materials and Fastenings[1]

By T. E. Piper,[2] K. F. Finlay,[2] and A. P. Binsacca[2]

Synopsis

Abstracts from numerous papers on the subject, in addition to observations in the authors' experience, contribute to the following conclusions:

1. Methods of evaluation of the fatigue characteristics of aircraft materials and fastenings must undergo drastic revision. Conventional testing procedures do not supply data significant to the severe conditions of dynamic loading found in aircraft of modern and anticipated design.
2. The establishment of significant criteria upon which realistic design can be based must necessarily be preceded by extensive tests involving interrupted dynamic test procedures.
3. So-called natural discontinuities of metallic structures are of growing importance to the students of ultra high-frequency loading.
4. It is incumbent on test engineers and metallurgists to forestall serious failures in aircraft resulting from failure to meet the requirements and conditions noted above.
5. It is a foregone conclusion that the *experience* is of little value during this time of revolutionary design and material requirements.

Up to the present time many applications of aircraft materials have been used because experience has shown that they have met fatigue requirements. Now that new and radical design is becoming more and more prevalent, and as higher strength materials are being developed, insufficient experience is available not only for specific materials but for assemblies, so that design can be made without imposing high fatigue safety factors upon materials or assemblies. Even as the airframe manufacturers continue to design and build military aircraft, a trend toward increasing the life span of not only fighters and bombers but also

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Presented at the Session on Fatigue of Metals held on October 10, 1949, at the First Pacific Area National Meeting of the Society, San Francisco, Calif.

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TABLE I.—SUMMARY OF TEST RESULTS FOR RIVETED JOINTS.
3/16-in. diameter 24S-T brazier head rivets in 1-in. wide lap joints (see footnotes).

Sheet Alloy	Thickness, in.	Specimen Number	Load per Rivet, lb.[a, b]	Corresponding Stresses, psi.			Number of Cycles	Type of Failure
				Tension	Shear[c, d, e]	Bearing[f]		
Alclad 24S-T	0.065	67793-1-0	1255	23 900	44 000	101 000	Static Test	Rivet
		-9	550	10 500	19 200	44 300	192 200	Sheet
		-11	525	10 000	18 300	42 300	231 500	Sheet
		-4	500	9 500	17 500	40 300	152 500	Sheet
		-12	420	8 000	14 700	33 800	337 900	Sheet
		-2	400	7 600	14 000	32 200	288 500	Sheet
		-10	350	6 600	12 200	28 200	924 100	Sheet
		-3	300	5 700	10 500	24 200	1 006 500	Sheet
		-7	240	4 600	8 400	19 300	3 999 900	Sheet
		-1	200	3 800	7 000	16 100	11 003 300	Sheet
		-8	185	3 500	6 500	14 900	100 617 500	None
		-6	170	3 200	5 900	13 700	100 526 700	None
		-5	150	2 800	5 200	12 100	100 302 900	None
Alclad 24S-T81	0.065	67793-2-0	1250	23 800	43 700	101 000	Static Test	Rivet
		-12	550	10 500	19 200	44 300	135 500	Sheet
		-11	520	9 900	18 200	41 900	200 400	Sheet
		-4	500	9 500	17 500	40 300	15 000	Rivet
		-6	490	9 300	17 100	39 500	133 000	Rivet
		-5	450	8 600	15 700	36 300	207 300	Sheet
		-3	400	7 600	14 000	32 200	350 300	Sheet
		-2	300	5 700	10 500	24 200	875 200	Sheet
		-1	200	3 800	7 000	16 100	2 459 100	Sheet
		-7	150	2 800	5 200	12 100	3 553 600	Sheet
		-8	120	2 300	4 200	9 700	13 890 700	Sheet
		-9	110	2 100	3 800	8 900	9 052 500	Sheet
		-10	95	1 800	3 300	7 700	103 154 700	None
Alclad 24S-RT	0.066	62968-1-0	1250	23 400	43 700	99 000	Static Test	Rivet
		-14	550	10 300	19 200	43 600	88 000	Rivet
		-16	550	10 300	19 200	43 600	178 500	Sheet
		-13	498	9 300	17 400	39 500	211 900	Sheet
		-12	400	7 500	14 000	31 800	522 400	Sheet
		-5	350	6 600	12 200	27 800	920 700	Sheet
		-3	300	5 600	10 500	23 800	1 104 000	Sheet
		-2	250	4 700	8 700	19 800	5 300 900	Sheet
		-15	225	4 200	7 900	17 900	17 918 100	Sheet
		-1	200	3 700	7 000	15 900	8 114 800	Sheet
		-4	175	3 300	6 100	13 900	28 973 900	Sheet
		-7	160	3 000	5 600	12 700	10 678 300	Sheet
		-8	140	2 600	4 900	11 100	40 962 100	Sheet
		-9	130	2 400	4 500	10 300	27 592 100	Sheet
		-10	120	2 200	4 200	9 500	69 060 600	Sheet
		-11	110	2 100	3 800	8 700	109 883 400	None
Alclad 24S-T86	0.066	62968-2-0	1250	23 400	43 700	99 000	Static Test	Rivet
		-15	549	10 300	19 200	43 600	115 600	Rivet
		-14	500	9 400	17 500	39 700	144 400	Sheet
		-13	400	7 500	14 000	31 800	312 600	Sheet
		-8	350	6 600	12 200	27 800	593 300	Sheet
		-1	300	5 600	10 500	23 800	897 100	Sheet
		-3	250	4 700	8 800	19 800	901 000	Sheet
		-2	200	3 700	7 000	15 900	2 188 600	Sheet
		-4	175	3 300	6 100	13 900	2 365 400	Sheet
		-7	175	3 300	6 100	13 900	2 804 700	Sheet
		-5	150	2 800	5 200	11 900	3 815 600	Sheet
		-9	135	2 500	4 700	10 700	5 561 800	Sheet
		-6	125	2 300	4 400	9 900	86 866 600	Sheet
		-10	120	2 200	4 200	9 500	49 852 200	Sheet
		-12	115	2 100	4 000	9 100	28 770 100	Sheet
Alclad 75S-T	0.066	63317-0	1270	23 800	44 400	101 000	Static Test	Rivet
		-10	550	10 300	19 200	43 600	144 900	Sheet
		-8	500	9 400	17 500	39 700	170 800	Sheet
		-7	400	7 500	14 000	31 700	318 500	Sheet
		-9	300	5 600	10 500	23 800	900 200	Sheet
		-2	200	3 700	7 000	15 900	4 267 200	Sheet
		-1	150	2 800	5 200	11 900	14 267 400	Sheet
		-6	135	2 500	4 700	10 700	103 987 300	None
		-3	125	2 300	4 400	9 900	16 668 000	Sheet
		-5	120	2 200	4 200	9 500	101 203 900	Sheet
		-4	110	2 100	3 800	8 700	103 745 600	None

[a] All specimens loaded across-grain.
[b] Four specimens loaded in each fatigue test; loads per rivet are average.
[c] Static shear strengths are average of three tests.
[d] Rivet shear stress based on hole area (diameter = 0.191 in.).
[e] Sheet stress based on net section through hole.
[f] Bearing stress based on hole diameter.

transports for military and civilian use is the order of the day.

In some instances we are aware that fatigue characteristics are satisfactory or that other properties are the controlling factors in design. In aircraft design the fatigue problem is increasingly serious and important. The following developments substantiate the urgent need for a thorough investigation of this mechanical property (1).[3]

1. The ultimate load factor has been successively decreased. Thus, stresses induced from repeated loads of various magnitudes are correspondingly increased and may fall above the fatigue limits of the structural parts.

2. Materials of higher strength, such as 75S, are being employed which often have rather poor fatigue qualities and high fatigue sensitivity for stress concentrations. Even though these materials have approximately the same absolute fatigue limit as older materials, the relative fatigue limit, that is, ratio between absolute fatigue limit and the tensile strength, decreases inversely as the ultimate strength is improved. In order to utilize fully the ultimate strength of the material or structural part for meeting the static load cases the relative fatigue limit is the property that is significant.

3. As competition increases and economical benefits of an increased payload are fully appreciated, static tests indicate that it is possible to cut down unnecessary material which reduces the extra margin of safety. This reduction as a rule impairs the fatigue qualities due to the fact that the over-all stress level is increased. Increased knowledge of designing for fatigue (reducing stress concentrations, etc.) is a desired trend, but in many cases this feature cannot compensate for the trend of reduction of material,

[3] The boldface numbers in parentheses refer to the list of references appended to this paper.

simply because the stress concentration factor cannot be reduced below a certain limit.

4. The cost of modern transport aircraft has increased to such an extent that there is a tendency to increase the life span of aircraft as mentioned before.

An objective proposed by one investigator (1) considering the tremendous growth that is upon us and anticipated in the aviation industry is that every action ought to be directed to completely prevent fatigue failures. This objective is one with the basic idea that aircraft shall be designed to prevent fatigue failures and could only be achieved if a standard requirement is accepted, that is, to withstand with safety the cumulative damage effect of all repeated loads occurring during the life span of the aircraft.

Satisfying such an objective would mean the determination of the expected spectrum of loads of various intensity and frequency to which aircraft in flight will be subjected during their life span. A determination of the fatigue life will then have to be made of the structure, either of individual assemblies or in its entirety. Realizing that such an undertaking would require years of extensive research and testing continued testing in the manner now being used will bring about a more complete understanding of the basic theoretical reasons for fatigue failure.

One investigator indicated that little or no investigation was contemplated on the fatigue problem and that many fatigue failures will occur before the designers are aware of this serious condition. This was true several years ago but increased activity in investigations into all fields of the fatigue problem has shown that everyone involved is now cognizant of this problem. Many investigations sponsored or run by corporations, societies, and committees are indicative of this trend and this résumé includes some of the results of these investigations on the fatigue characteristics of aircraft materials and fasteners.

Fatigue Characteristics of Joints

Bolted Lap Joints:

Investigation on the fatigue characteristics of bolted lap joints of 24S-T Alclad sheet materials (2) indicated that bolt fit (bolt clearance varied from −0.0005 to +0.050 in.) has no pronounced influence on joint strength under unidirectional loading and that under reversed loading the influence also seems to be slight. Limited tests on the interference fit of lockbolted lap joint of 24S-T Alclad (3) also indicated that there was no significant effect of fit upon lifetime to fatigue. From this analysis it appears that the fatigue strength is not influenced by bolt fit, but it should be emphasized that loose fitting bolts permit objectionable slip and joint deflection and are undesirable.

Two or more bolts in line with the load increase the fatique strength but not in proportion to the number of bolts used. For a given bolt diameter and bolt pattern, increasing the sheet gage (0.102 to 0.375 in.) increases the long-life fatigue strength but not in proportion to the increase in gage. Additional tests employing steel bolts, as were the tests made above, indicate that countersunk bolts may produce lower fatigue values than joints made with hexagonal headed bolts. Also, with bolts of different diameters the fatigue strength will vary with diameter-thickness ratio.

Flush-Riveted Joints:

Flush-riveted joints (4) made on 24S-T aluminum alloy plate with A17S-T aluminum alloy rivets indicate that the fatigue strength of the rivets in completely reversed shear was greatest for commercial countersunk rivets with the head 0.010 in. above the plate surface before driving, while it was lowest when the head was 0.003 in. below the surface. Reverse-driven rivets caused the fatigue strength to be intermediate between these extremes as noted below even though they developed the highest static ultimate strength.

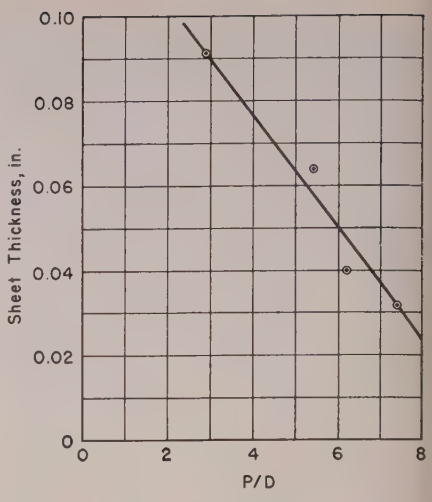

Fig. 1.—Variation of Optimum Ratio of Rivet Pitch to Rivet Diameter with Sheet Thickness.

Spot-Welded Joints:

Fatigue tests on spot-welded sheets of 24S-T Alclad aluminum alloy sheet (6) indicate that the fatigue strength of a spot-welded joint in sheets of two different gages is slightly higher than that of a similar joint in two sheets of the thinner gage but definitely lower than that of a similar joint in two sheets of the thicker gage. Spot welding of Alclad 75S-T indicated that they were not any stronger in fatigue than similar specimens of Alclad 24S-T. In general, it can be stated that spot-welded lap joints which gave the highest static strength produced also the highest fatigue strength. Riveted joints, in general, were stronger in fatigue than corresponding spot-welded joints. It should be noted that in comparing spot-welded materials several factors should be considered in evaluating fatigue characteristics: the relative strengths of bare sheet materials, the effect of cladding, and the type of spot weld.

Previous work on spot welding of 24S-T Alclad (7) indicated that, in general, welds with the greatest penetration and rivet area per inch will usually be dictated by static strength requirements, it is possible by use of Fig. 1 to choose a value of p/d that will ensure that the joint is well proportioned to resist alternate "prying" loads and will consistently meet the static strength requirements.

	Series CA	Series CB	Series CC	Series NA
Static ultimate strength, psi	31 500	32 500	35 500	38 100
Endurance limit at 10^7 cycles psi	9 300	12 900	15 000	11 000
Endurance limit / Static ultimate strength, per cent	30	40	42	29

The ratio of rivet pitch, p, to rivet diameter, d, on the fatigue strength of riveted A17S-T aluminum alloy rivets bent-up flanges of 24S-T aluminum alloy sheet (5) definitely affects the fatigue strength of this method of fastening. It was concluded that for each sheet thickness of material there is an optimum value of p/d for which P_f/P_u ratio is a maximum, where P_f is the fatigue strength and P_u is the static ultimate strength as noted in table below.

Sheet Thickness, in.	Optimum Value of p/d for Maximum Value of P_f/P_u
0.091	2.9
0.064	5.4
0.040	6.2
0.032	7.6

Since in a riveted joint sheet thick-

trations, amount of dendritic structure, and diameter possible, will prove strongest under dynamic loadings. It has also been found that static shear strength increases with increased diameter but decreases with increased penetration.

One investigator has determined that in stainless steel, spot-weld button quality is subordinate in importance to weld diameter. He further concludes that multiple spot welds of a given total area cannot be practically or ideally spaced to prevent interaction which becomes a detriment to fatigue joint efficiency, as compared to the single spot. Certain support is given by this analysis to the efficacy of seam or roll welds in large joints.

Conclusions

In general, the fatigue strength of joints in sheets and plates cannot be predicted directly from the fatigue strength of plain sheet specimens of material. A more probable correlation is that relating the fatigue strength of joints to those of notched sheets, but it is not known what type of notch or stress concentration factor would provide the best correlation. The influence of sheet properties is usually less than that of stress concentrations inherent in the type and fabrication of the joint.

Relative fatigue tests of riveted joints of aluminum alloy sheets (**8**) subjected to different number of cycles are shown in Table I. These samples were riveted with $\frac{3}{16}$-in. diameter 24S-T, with brazier manufacture heads and flat driven heads.

Discussion of Fatigue Strength

Axial fatigue tests at zero mean stress have been made on 0.032- and 0.064-in. 24S-T and 0.032-in. 75 S-T sheet metal specimens $\frac{1}{4}$, $\frac{1}{2}$, 1, and 2 in. wide without a hole and with central holes giving a range of hole diameter, d, to specimen width, w, from 0.01 to 0.95. No systematic difference was noted between the results for the 0.032-in. and the 0.064-in. specimens although the latter seemed the more consistent. In general, the fatigue strength based on the minimum section dropped sharply as the ratio d/w was increased from zero to about 0.25. The plain specimens showed quite a pronounced decrease in fatigue strength with increasing width. The holed specimens showed only slight and rather inconclusive evidence of this size effect. The fatigue stress-concentration factor was higher for 75S-T than for 24S-T alloy. Evidence was found that a very small hole would not cause any reduction in fatigue strength.

The classic definition of fatigue strength or endurance limit, "...the stress below which a material will withstand an indefinitely large number of cycles of stress without failure," should be emphasized in a different light than has been our custom in the past. It is not fanciful in these times to speak of "Death Rays" which destroy organisms or man-made engines. By the same token of our ingenuity in producing ultrasonic engines, is it not feasible to create harmonics and dissonant vibrations which may substantially decrease the normal life expectancy of materials?

Notable theories proposing explanations for creep, yielding, and fracture of metals are based on atomic bonds, electromagnetic potentials, submicroscopic cracks, dislocations, etc. Begging indulgence of the liberty to theorize beyond the theorists, it is interesting to contemplate the relationship between the ultra-high frequencies of our present-day engines and their effects on the structures of metals.

Hysteresis in terms of magno-restriction has a parallel phenomenon in the natural permeability of materials to absorb mechanical energy. The transmission of mechanical energy through material on sonic or ultrasonic frequency levels induces an unpredictable, however damaging, effect in the material. Whether the failure origin is an atomic scale dislocation or submicroscopic cleavage-plane, the debilitating effects of the high-frequency loading are apt to have much more far-reaching effects than those found in the pre-gas turbine era.

The aspect of elevated temperatures combined with the severe type of loading peculiar to high-speed aircraft gives further food for thought. The normal decrease of cohesive strength of materials at elevated temperatures is elementary. The energy-absorbing property of metals often decreases at elevated temperatures. The inability to absorb energy involves a preferred distribution of vibrations or stress in the areas most susceptible to relief. Further projection of theory might well include a premise that for a given material, stresses are more likely to seek out an incipient fracture when transmitted by high frequency than by low frequency.

The proposal has already been introduced to the services through the National Advisory Committee on Aeronautics that a new philosophy of testing is required to evaluate materials in the face of our expanding horizons in physical metallurgy. Evaluation of the problems must certainly precede evaluation of the materials. It has been demonstrated that simulated service test procedures which aim at maximum conditions of fatigue loading at operational temperatures do not accurately foretell service-life expectancy when short-time test methods prevail. The progressive nature of fatigue failure leaves no room for argument against the wisdom of interrupted testing which produces cumulative data.

If we are justified in stating that lower fatigue strength in specimens of identical geometry and structure will result from higher frequency of application at a given load, then we may predict that the scatter-band of fatigue strength for a given material will probably be narrower than at lower frequency fatique strengths—but at a lower mean strength level.

The relative susceptibility to fatigue failure of various sections of formed and thereby pre-strained areas in airframe structures has been largely disregarded. Returning to the basic characteristic of fatigue failures, namely nucleation, it is of serious concern to try to anticipate the effects of the numerous slip planes or twinning discontinuities in worked materials. It seems inevitable that unless due consideration is given these effects in preference to the ultimate strength phobia which designers and production people suffer from, physical metallurgy limitations may inhibit the natural progress of the industry to a serious degree.

In conclusion it would be well to emphasize that whereas *experience* has been our criterion for appreciation of the fatigue characteristics of aircraft materials and fasteners, the revolutionary design and material requirements of modern and projected aircraft have far outdistanced *experience* and it behooves us to conduct extensive revision of the philosophy of fatigue testing.

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DISCUSSION

Mr. A. C. Carlson[1] (*presented in written form*).—As stated by Mr. Piper, aircraft structures are now designed with greater structural efficiency than aircraft structures designed years ago. This is the result of a greater knowledge of the loads placed on the structure, an improvement in design technique, and an increase in the ultimate strength of the materials. With these changes has occurred a basic change in the type of structure being used. Instead of the former practice of concentrating the load-carrying material at spars or longerons, in general we now utilize monocoque-type construction which distributes the load-carrying materials over a considerable width of the wing or fuselage. Thus, for the majority of the structure a failure of one component, which is the case in fatigue failures, will not cause a complete failure of the wing structure, and the local fracture can be detected by routine inspection before the over-all load-carrying capacity of the wing is substantially reduced. Where it is necessary to concentrate a large portion of the load-carrying material in a limited area, such as at spars, or in the vicinity of a major cutout, particular attention is given to the selection of the most favorable material from a fatigue standpoint and to the usage of a detail design which has a minimum of stress concentrators.

Greater efficiency in design does not necessarily mean that lower fatigue strength is obtained, because improvement in the detail joint configuration obtained by knowledge of how to increase joint efficiency can result in the same net area stress for both the original and the improved design.

Mention should be made of improvements in fasteners such as tension bolts. The industry is now using bolts with rolled threads instead of the former cut or ground threads. Although no increase in allowable stress has been made, the fatigue life of the presently used bolts is more than twice that of cut or ground thread bolts. An additional increase in fatigue life is possible through the adoption of bolts with rolled head to shank fillets, which is now being considered.

The service life of aircraft cannot be predicted at the present time because of the large number of variables and numerous items which are not now completely evaluated. However, aircraft are now designed with specific consideration for the obtaining of an extended service life. Information has been and is being obtained on the comparative fatigue properties of various materials and various types of detail design, on the type and frequency of the loads to which the aircraft are subjected, and on the variation of loading encountered under various conditions.

The blanket substitution of higher strength material with higher allowables using past detail design configuration is not the current design policy. The past service history of individual airplane models provides an excellent indication of the ability of certain types of design and of certain materials to sustain the repeated loading encountered in service operation. This service history, when all of the influencing factors are considered, can provide a general guide for current design practice.

It is granted that we have limited knowledge of the structural loading encountered in transonic or supersonic aircraft. However, limited experience in the field of gas turbine engines dealing with high-frequency loading of turbine blade configurations has revealed numerous problems, but there has been no evidence to date which would indicate that the material behavior differs from that encountered in normal frequency loading.

Mr. M. H. Weisman.[2]—Mr. Carlson contends that the increased structural efficiency of current design practices has not resulted in decreased fatigue strength of aircraft structures. In general, this is true. The increased care taken to reduce the severity of stress concentration in detailed design and the application of such practices as rolled threads and shot-peened surfaces produce parts far superior in fatigue strength to those of the past.

It should be pointed out, however, that the primary design criterion for structural parts in most cases is still the static ultimate strength. Only where prior experience or actual test failures indicate the need are the lower fatigue strength allowables used.

The use of materials with higher ultimate and yield strengths, such as 75S-T, has caused some difficulty. Such materials are more notch-sensitive than the materials which they replace. As a result, the fatigue allowable for the new high-strength material is often no higher, and actually may be lower, than the fatigue allowable for the previously used material of lower ultimate strength. Stress concentrations, including tool marks and service damage, or conditions of loading which were unimportant in the past, now can cause trouble because of the greater detrimental effect on parts made from the new high-strength materials.

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Flow Calculations for Die Casting Applied to the A.S.T.M. Committee B-6 Test Casting Die

By Edward Jacobi[1]

Synopsis

The equation of steady flow in filling a die-casting die is derived and solved for a range of pressures, velocities, and gate orifices. The relation to optimum die-casting die design and operation is indicated.

The flow of metal in die casting is of importance and interest because it is a factor in producing satisfactory castings. The velocities of flow in the supply channels of the die and along the walls of various parts of the die cavity, as well as the rate at which various sections of the die cavity are filled, must be in certain relations or ratios to the rate of heat abstraction through the die walls. There must also be correct relations between those velocities and the rate at which air is vented from the die. These relations determine the soundness of castings and their surface finish.

The dependence of those velocities upon the pressure applied to the metal is of prime importance in operating die-casting machinery to produce satisfactory castings. The dependence of the flow velocities upon metal temperature, alloy composition, and other factors may also prove to be worth considering. The machine operators adjust the applied pressure as well as other factors, such as metal temperature and die cooling, and they find a balance of operating factors that produces a satisfactory product. Sometimes the limits of the ranges of operating factors are narrow, slight deviations producing critical effects. However, it is notable that castings of comparable good quality have been produced from test castings of the Committee B-6 design under both the conditions of high applied pressure with low injection plunger velocity, and of low applied pressure with high plunger velocity.

Instruments are available for measuring the total time of the injection plunger stroke. Also, laboratory instruments have been developed for determining the instantaneous motion of the injection plunger at all portions of its stroke. From such laboratory instruments for instantaneous plunger motion, the velocity of the metal flow can be inferred by making the assumption that the channels are filled from the point at which the velocity is being determined back to the plunger.

In published studies of die casting, the pressure applied to the metal by the injection plunger usually has been assumed to be the pressure at the hydraulic system pump or in the accumulator tank, multiplied by the ratio of areas of fluid power piston to metal plunger. The distance from the pressure gage to the fluid piston may be several feet. The fluid may have to move at fairly high momentary velocities as the plunger makes its stroke, and friction must be overcome at pipe and valve changes in direction as well as mechanical friction in the plunger. Thus the actual instantaneous pressures may depart widely from the nominal pressure.

For the purpose of gaining accurate knowledge of how changes in the die-casting machine pressure adjustments affect the injection pressure and velocity as well as how the efficiency and control of the machine may be improved, a means of measuring metal pressures is a desideratum. A means of measuring velocities directly, as by detecting the heat or pressure effects of the passing stream of metal in the die, would also be an aid to future research work. However, until such instruments become generally available, the flow could be calculated.

The general arrangement of the injection mechanism of cold-chamber die-casting machines is shown diagrammatically in Fig. 1. Only the essential elements are indicated, small details being omitted. Some machines operate with a vertical plunger instead of the horizontal plunger shown. However, they have the same elements and their operation is similar.

The relations between metal velocity results and such factors as applied pressure and metal temperature may be approximated by calculation closely enough, it is believed, to serve for the direction of research work and for interpreting and analyzing the data found with present available instruments.

After the metal plunger has transferred the molten metal charge from the cold chamber through the cylinder to the sprue, filling the runner and commencing to discharge at the gate into the die cavity, the plunger travels at a steady speed for a while until the die has been filled back to the gate. This steady motion of the plunger and steady flow in the die runner and gate may be computed by simple methods for a range of pressures, gate opening sizes, and consequent velocities. This computation is the object of the present study.

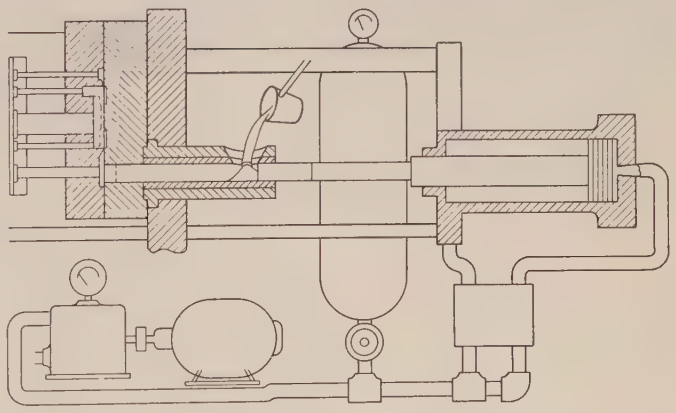

Fig. 1.—Diagram of Cold-Chamber Die-Casting Machine.

The initial flow before the die channels are filled and the final rise in pressure after the die is filled are not considered here, because these transient phenomena are not pertinent to the objective of calculating the rate of mold filling, which determines the soundness and surface finish of the casting. If they were important, these initial and final phenomena could be calculated for their velocity and duration by setting up the appropriate differential equa-

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tions (1)[2] and calculating the solutions for ranges of operating conditions. However, they are probably a minor fraction of the total time of filling the die and are therefore unimportant. The total time of filling the die is perhaps one-hundredth of the cycle time of the die-casting machine from one cast to the next. Therefore, the time durations of the transient initial and final flow phenomena are unimportant from the standpoint of their effect on production as well as on the rate of solidification of the castings; and any changes in the durations of these transient initial and final events due to adjustment of operating conditions are readily compensated for by a slight change in the cycle time. The present study will be restricted accordingly to steady flow.

The purposes of this study were the following:

1. To setup a common basis for analyzing operating data to be gathered in experimenting with the Committee's research dies.
2. To determine the ranges of nominal gate velocities for various sizes of gates, within which ranges satisfactory castings can be made at various temperatures.
3. To derive the flow equations in such general form that they could be setup for other kinds and sizes of molds, such equations to be used to ascertain whether the same ranges of velocities, as in the present die or other ranges, are necessary in other dies.
4. To give formulas by which the actual pressures and velocities measured in die casting dies might be used to investigate pressure losses and efficiency of the hydraulic system of the die-casting machine.
5. To offer equations which may be transposed to yield new and more accurate flow coefficients for the hydraulic friction of metal flow in die-casting mold channels. By substituting in these equations the measured velocities and pressures in tests of die-casting molds, these equations may be solved to give tested values of the flow coefficients.

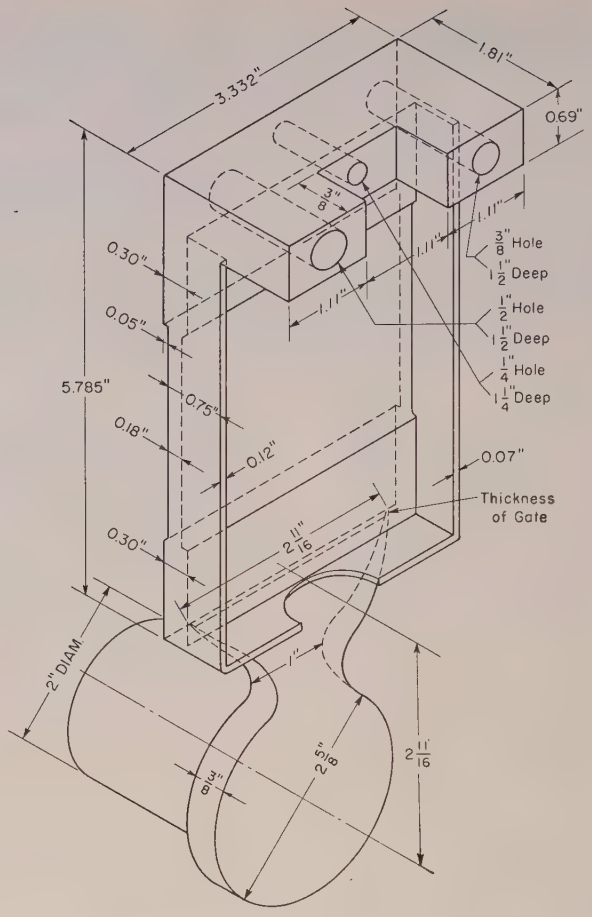

Fig. 2.—Committee B-6 Test Casting and Attached Sprue and Runner.

TABLE I.—GATE VELOCITIES AND FILLING RATES.

Thickness of Gate, in.	A_G, Areas of Gate, sq. ft.	V_G, Average Velocity in the Gate, ft. per sec.	p_m, Actual Pressures on the Metal, lb. per sq. ft.	Die Filling Time, sec.	Average Speed of Filling the Die Evenly (Rate of Progress Along the Die Walls), ft. per sec.	
					At the Thick Legs	At the Thin Middle Plate Section
0.030.....	0.0005479	166	68 810	0.063	6.52	16.8
		234	136 880	0.0456	9.20	23.68
		380	362 600	0.0276	14.92	38.44
		490	602 530	0.0214	19.25	49.6
		590	873 210	0.0177	23.2	59.7
		740	1 373 070	0.0142	29.16	74.8
		970	2 358 140	0.0108	38.10	98.2
0.035.....	0.0006392	166	68 932	0.054	7.60	19.57
		234	136 933	0.0383	10.71	27.60
		380	363 480	0.0236	17.4	44.8
		490	603 965	0.0183	22.4	57.7
		590	875 200	0.0152	28.0	69.5
		740	1 376 030	0.0121	33.9	87.2
		970	2 362 890	0.0093	44.4	118.0
0.050.....	0.0009132	166	69 220	0.0377	10.9	28.0
		234	137 485	0.0268	15.3	39.4
		380	366 830	0.0165	24.9	64.0
		490	609 108	0.0128	32.1	82.5
		590	882 490	0.0106	38.6	99.3
		740	1 386 830	0.0085	48.4	124.5
		970	2 380 284	0.0065	63.5	163.0
0.080.....	0.0014611	166	70 023	0.0235	17.4	44.7
		234	138 955	0.0167	24.5	63.0
		380	376 087	0.0103	39.8	102.0
		490	623 670	0.0080	51.3	132.0
		590	902 530	0.0066	61.8	159.0
		740	1 416 820	0.0053	77.5	199.0
		970	2 427 860	0.0041	101.0	261.0

Scope of the Present Study

The equation for flow in the various parts of a die-casting die is derived for any simple form of die having a single cavity and a single gate opening, thus having no branching flow and no question of distribution. It is then applied to the committee's design of test casting die by substituting the numerical dimensions of the die channels in the equation. This produces a special, simplified form of equation applicable to this particular die. The dimensions of the metal receiving channels and cavity of the die are given in Fig. 2, which is a perspective drawing of the casting and its attached sprue. Three overflow receiving chambers and the vents are omitted from this figure.

A range of gate velocities corresponding to the generally used range of pressures is substituted in the special equation for this die, at each of several gate slot thicknesses commonly used in dies of this size and kind. The solutions thus found are the particular pressures in the molten metal in front of the plunger corresponding to these assumed velocities and gate openings.

[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

The solutions are collected in Table
Some of these combinations of
perating factors may be outside the
mits of satisfactory casting.

Possible Application to the Improvement of Gate Design

These tabulated results, if related to
ie velocities at which this die can be
perated successfully, will indicate how
ate areas influence casting operating
onditions and results. By further
udy of these figures in the light of
perating data, the limits of the operat-
g factors of pressure, temperature,
c., also may be found. It may be dis-
overed that certain gate sizes allow of
ore variation in these operating fac-
rs than other gate sizes, thereby
ointing to the most favorable gate de-
gn.

Such a predetermination of the most
vorable gate design would be an im-
rovement on the usual method. This
onsists of cutting a gate opening rather
naller than one that produced satis-
ctory castings on a similar die. The
irection and location of injection are
nportant, of course. The dies being
ompared should produce castings that
ave approximately equal wall thick-
esses and areas, so that the cooling rate
nearly the same. The castings should
ontain approximately the same vol-
mes of metal so that the dies will fill
milarly.

The gate opening is usually cut
ather small to allow for correction of
asting deficiencies by cautiously en-
rging the gate thus avoiding the
ecessity of correcting too large a gate
y the more difficult operations of weld-
ng or of inserting a new gate insert into
he die. As a consequence, the best
ate size, from the standpoint of the
est castings as well as the widest
titude in pressures, metal tempera-
ure, and cooling speed, may not be
ound because too many experiments
ould be needed and too much die work
n preparing various gate openings
ould be involved to find the best com-
inations. The experimentation gen-
rally is terminated when satisfactory
astings result from some one combina-
ion of pressures and temperatures.

Calculation of Equations for Die-Casting Flow

The computations are offered as ap-
roximations to the velocities and fil-
ing times. They are based on steady
low conditions. No attempt is made to
llow for the gradual start from rest, of
he plunger and of the flow of the metal.

The assumptions are:

1. At the beginning of the injection
ime, the sprue, runner, and gate are filled
nd the metal just begins to emerge from the gate. The metal jet and the plunger are at a steady velocity at this instant and throughout the time of filling the die.

2. The pressure on the plunger is steady and there is no acceleration of the plunger motion and of the metal stream during the stroke. The energy imparted to the moving metal before the beginning of metal discharge at the gate is taken into the "velocity of approach" term V_P in the first term of the right-hand member of the energy equation below.

3. There are no voids in the body of molten metal from the gate back to the plunger. The gate discharges a solid stream of the cross-section of the gate. Of course, the streams of metal inside the die cavity do not generally fill the passageways through the cavity until the cavity becomes filled in some of its parts. The die cavity is assumed to fill first in its parts that are most remote from the gate and then to fill progressively backward of the direction of flow until the parts around the gate are filled last.

4. There is no term in the equation to represent the back pressure of the air in the die cavity as the air is displaced by the incoming metal and discharged through the vents.

An equation of the energy balance per stroke may be written as:

$$p_m A_P L_P = (V_G^2 - V_P^2)W/2g + p_R A_R L_R + p_E A_R L_R + p_G A_G L_G + zW$$

Effective energy imparted to the metal by the metal plunger	Kinetic energy of injected charge	Loss of energy in the runner	Loss of energy at the entrance of the runner	Loss of energy in the gate	Work of lifting the charge from the plunger to the gate

The A's are areas and the L's are the lengths of the charge as it is formed and confined in the various channels of the die.

A_P is the area of the metal plunger = 0.02182 sq. ft., the plunger diameter being assumed as 2 in.

A_R is the area of the runner at the narrowest place in square feet = 0.0023177 sq. ft., equivalent to 0.3375 sq. in. The narrowest place happens to be close to both the edge of the plunger and to the place where the runner is narrowed in thickness to approach the gate. Therefore, the runner does not vary greatly in area through its short length.

The A_G's are the areas of the various gates calculated, expressed in square feet.

All numerical values throughout are carried out in consistent units of feet, pounds, and seconds.

The various lengths of the charge in the various channels of the die are:

L_P = the length of the plunger stroke, in feet, after the runner is filled,
L_R = the length of the charge, in feet, as it passes through the runner, and
L_G = the length of the charge in feet as it passes through the gate.

The various volumes indicated by the products of lengths and corresponding areas are all taken equal to one another and are taken equal to the volume of the die cavity plus the overflows, but excluding the gate and the runner. The continuity of flow assumed here implies no voids nor cavitation at steeply diverging tapers. Actually, though, the thin but broad slot of the gate may not be filled across its entire breadth at any one instant, but a stream of less width may oscillate from side to side of the gate. In experiments in which it was attempted to discharge ribbons of mercury from thin but broad slots in revolving drums for mercury jet interrupters, the slot was not kept filled but a narrower ribbon issued from the slot (2). Such a result would tend to increase the velocity of flow in the gate and would change the coefficients in the terms representing friction flow losses.

Then, continuity being assumed

$$A_P L_P = A_R L_R = A_G L_G = 0.005715 \text{ cu. ft.}$$

The weight of the charge = W = 0.005715w. in pounds (w = the weight per cubic foot of the molten aluminum alloy, which is taken as 160 lb. per cu. ft. at 650 C. (1200 F.)).

The equal volumes may be factored out of all terms of the energy equation, reducing it to

$$p_m = (V_G^2 - V_P^2)160/2g + p_R + p_E + p_G + z \times 160$$

p_m is the actual pressure in the metal in the cold chamber. The assumption that it is equal to the hydraulic system pressure in the pump or accumulator multiplied by the ratio of hydraulic piston area to metal plunger area may lead to serious discrepancies because of friction losses in the piston and the plunger, fluid friction losses in the hydraulic system, etc. Reliable means must be found for evaluating the actual metal pressures.

g = the acceleration of gravity, 32.16 ft. per sec. per sec.
V_G = the velocity in feet per second of the metal flowing through the gate jet, the average of the velocities at all points of the gate cross-section being meant,
V_P = the uniform velocity in feet per second of the metal plunger = $V_G A_G / A_P$,
V_R = the average velocity across the runner cross-section in feet per second = $V_G A_G / A_R$

V_E = the average velocity at the entrance of the runner in feet per second (in this present die design, $V_E = V_R$), and

p_R = the loss of pressure in the metal, in pounds per square foot across the smallest cross-section of the runner, due to fluid friction in the runner = $0.133(\mu)^{1/4} l \rho^{3/4} V_R^{7/4} / 2 r_R^{5/4}$ (3).

At the two lowest steps of pressure computed and tabulated below, namely, approximately 68,000 lb. per sq. ft. and 137,000 lb. per sq. ft. the Reynolds numbers are less than 200,000. For the steps above 137,000 lb. per sq. ft. the Reynolds numbers will be in a higher range, which will require that the coefficient $\lambda = 0.133\,(R_E)^{-1/4} = 0.133\,(\mu/V_R \rho r_R)^{1/4}$ be replaced by the modified form at the foot of page 42 of reference 3, or by that of Drew, Koo, and McAdams (12). This has been done in the computations of the higher pressure and velocity steps as shown in Table I. The modified $\lambda = 0.00357 + 0.3052/(2R_E)^{0.35}$. Then in that higher R_E range,

$$p_R = V_R^2 \times 0.058 + 0.3052 l \mu^{0.35} \rho^{2.0-0.35} V_R^{2-0.35} / (2 r_R)^{1.0+0.35}$$

μ is the viscosity of the molten aluminum alloy. The viscosities of pure aluminum and of aluminum alloy have been published for ranges of temperatures (4). The values given for silumin at 650 C. are 0.04036 and 0.03960 poise. Take 0.040 as the mean. As consistent pounds, feet, and seconds units must be used throughout the calculations, this 0.040 value must be multiplied by the factors 6.85/-0.0328 $\times 10^5$ to express poises as slugs per ft. $\times$ sec. (5).

l = the length of the runner in feet, 2.125 in./12,

ρ = the density of the metal in slugs per cubic foot, taken as 160/32.16 = 4.97,

r_R = 0.02725 ft., the radius that corresponds to the area A_R,

p_E = loss of pressure in the metal in pounds per square foot due to hydraulic friction losses at the sharp-edged circular entrance to the runner and at the abrupt quarter turn. $p_E = (0.5 + 1.0) V_R^2/2g$ (6, 7, 8), and

p_G = loss of pressure by friction in the gate = $0.15 V_G^2/2g$ (5, pp. 293, 288, 95, 96, 103, 295; 8, p. 136; 9).

The validity of applying these coefficients is based on noncompressibility (5, p. 206). Molten metals are probably only very slightly compressible as compared to water, if we may reason from the known low compressibility of mercury and its slight change in viscosity under high pressure (11). Liquids of large molecule structure such as oils are known to be more compressible, and their changes in viscosity are relatively enormous (5, p. 178, 179; 10).

The pressure loss coefficients 0.5, 1.0, and 0.15 in p_E and p_G are probably reasonably accurate if there is no cavitation in the channels. Examination of the flow markings might verify this. The critical diverging angle of 6 deg. for water, at which a marked rise in loss occurs, should be recalculated for molten metal or investigated physically (3, pp. 54–56; 5, pp. 293, 288, 95, 96, 103, 295). Any excessive increase in channel area at above the critical rate of divergence may markedly increase these coefficients. That, in turn, would affect the die filling time.

$z \times 160$ is the pressure head in pounds to be overcome in lifting the metal through the height, z in feet, from the center of the plunger to the gate discharge side. As this is a small fraction of 1 per cent of the least metal pressure being considered in these computations, this term will be omitted in all the subsequent work.

Simplified Flow Equation for the Committee's Die

The above equation of pressures may now have substituted in it the numerical values relating to the die under consideration. The flow equation of the die then reduces to

$$p_m = V_G^2(2.49 + A_G^2\,4300) + V_G^{7/4} A_G^{7/4} \times 13{,}800$$

This applies to Reynolds numbers under 200,000. The gate velocities below 300 ft. per sec. in Table I, and metal pressures below 200,000 lb. per sq. ft. correspond to Reynolds numbers in the lower range. For higher Reynolds numbers and high gate velocities, the modified coefficient λ above is substituted. For those higher velocity and pressure ranges,

$$p_m = V_G^2(2.49 + A_G^2 \times 15{,}010) + V_G^{1.65} A_G^{1.65} \times 31{,}460$$

To produce Table I, various assumed uniform gate velocities, V_G, and gate areas, A_G, have been substituted in these equations to ascertain the corresponding unit pressures p_m on the metal in the sprue. The corresponding theoretical time, or nominal time in seconds to fill the die, readily follows from the various assumed gate velocities. The time to fill the die is based on uniform plunger velocity during the die-filling portion of the plunger stroke and is based on the gate cross-section being full. The formula is simply 0.005715 cu. ft./$A_G V_G$. The sixth and seventh columns of Table I are the nominal speeds of filling the die if the metal were poured through the gate at the stated gate velocities and gate areas and were to fill respectively the thick portion of the casting at the legs near the upper end and the thin plate section near the middle of the casting length. In other words, the figures in the sixth and seventh columns are the rates at which the molten metal would fill in along the walls of these portions of the die, if the filling operation were to proceed in an ideal uniform manner. Actually, as shown by etching flow lines, the metal streams from the gate and, striking cores, die corners, and other obstructions, eddies laterally and backward into die recesses nearer the gate before the most remote recesses are filled.

However, these nominal filling rates taken in comparison with the time of solidification of the surface film of the casting under various metal die temperature circumstances, may lead to criteria of operating conditions for satisfactory castings from the standpoint of surface finish and cold shuts. The metal streams mentioned in the preceding paragraph heat the mold surfaces by continuing to wash over them and do not make visible flow marks and cold shuts. Therefore, the above filling rates may be found useful, if studied.

The cross-section of the thick portion of the casting at the legs has been computed as 0.01394 sq. ft. The formula for the filling velocity at this portion is $A_G V_G/0.01394$. The cross-section at the thin plate including the side ribs is 0.00542 sq. ft.

Possible Further Applications of This Analysis

The flow equations might be applied in another way. They could be used to find coefficients. If measurements can be made in the molds to ascertain the metal pressure and filling time under steady-state conditions, or with accurate allowances for accelerating of the plunger and variations in metal pressure through the stroke, then the implied velocities can be ascertained. The velocity and unit pressure can then be substituted in the equation, and an over-all coefficient be found. By repeating this process with various values the coefficients for various portions of the channels might be derived by elimination between the simultaneous equations thus formed.

The over-all coefficient of discharge could be measured on the die, in the absence of instrumentation for measuring metal pressure, by setting up the die to allow of pumping water through at pressures that will produce Reynolds numbers equivalent to the ranges of velocities used with molten aluminum. The discharge at a steady rate would be caught and its volume measured.

The coefficient for the runner alone

ould be measured by removing the gate sert. Similarly the discharge characteristics of various gates could be measured by themselves.

If the instantaneous plunger speed an be measured accurately, and if the ate cross-section can be proved to be ept filled so that $V_G = V_p A_p / A_G$ is rue, the pressure on the metal can be omputed from V_G and compared to the ominal metal pressure delivered by the ydraulic system. This would give an ndication of the magnitude of losses in he hydraulic system.

Another interesting study, which ould be carried out merely by computaion from the available data, would be lot the properties of molten silumin ver the range of casting temperatures sed in practice. The data of Polyak nd Sergiev (4) might be used, or any thers available. The density variation f the metal with temperature can be alculated, or data might be looked up. hese constants could then be inserted nto the flow equations, to find how uch change in velocity and filling time ould be produced by varying the castng temperature through its ordinary ractical range.

The magnitude of the work performed n the metal when forcing it into the die might be considered *per se*. All of the energy imparted to the charge is expended in friction and in accelerating it from rest. Both are converted only to heat, the latter when the stream strikes stationary surfaces in the mold cavity. Therefore, for any particular case, $p_m A_p L_p$ ft-lb. are expended in heating the charge and the die cavity walls locally. If the energy would be entirely applied to heating the charge, $p_m A_p L_p / 778.1 = 0.005715 \times wtc$, in which w is the weight per cubic foot of aluminum alloy (160 lb.); t is the rise in temperature in deg. Fahr.; and c is the specific heat 0.2510 of aluminum at 1250 F. $A_p L_p = 0.005715$ cu. ft. Then at a pressure on the metal of 875,200 lb. per sq. ft., the metal temperature in the casting would be raised 28 F., if the energy is used in heating only the casting. It would actually be less than this, perhaps half as much, since some of the friction and impact heat passes into the die blocks. The heat that passes into the walls of the die is probably localized in projecting corners of the die and at the gate constriction.

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A New Technique for Bond Measurement in Reinforced Concrete

by J. Trueman Thompson[1] and Alvin C. Loewer, Jr.[2]

The time-honored way o determine the bond stress between oncrete and steel is to measure the orces and displacements which occur hen a steel bar is pulled out of a block f concrete in which it is embedded. his is a well-known procedure. But he principal deficiency of the method also well recognized—that the stress h the bar decreases with the length and ondition of embedment from a maxium at the point where the bar enters he concrete, to perhaps zero at some oint in the embedded length. If the ull-out force and length of embedment re great enough, bond failure will occur ear the point where the bar enters the oncrete before any bond stress is produced at the opposite end.

Obviously, it would be desirable to retain the simple concept of this "normal" pull-out test and at the same time avoid its main inadequacy by producing, as nearly as possible, a uniform bond stress throughout the embedded length. Then it would be possible to study the development of bond stress through a range of values from inception to failure. An approach to this ideal was attempted by the junior author in connection with dissertation research on bond phenomena at Johns Hopkins under the direction of the senior author. His experiments will be referred to as "modified" pull-out tests.

Description of Test Specimens

In order to approximate uniform distribution of bond stress, a system of telescoping steel tubes was devised by which it was hoped to transmit predetermined forces to embedded segments of tubing 1 in. in outside diameter and approximately 1 in. in length in the direction of the pull. Five-segment specimens were employed, with a total embedment of approximately 5 in. The lengths of the bond segments varied somewhat because transmitting tubes were not available of precisely the cross-sectional area necessary to transmit exactly equal forces. By varying the lengths of the segments slightly, a surface area was provided in each segment so that, when acted on by uniform bond stress, the segment would provide a resisting force equal to that transmitted to it by the particular transmitting tube to which it was attached. These forces varied directly with the cross-sectional areas of the available tubes and inversely with their lengths.

Figure 1 shows an assembly sketch of a five-segment bar specimen with the separation between segments greatly exaggerated so as to reveal the internal arrangement including the lead wires connected to the several electric strain gages. Actually, the ends of the seg-

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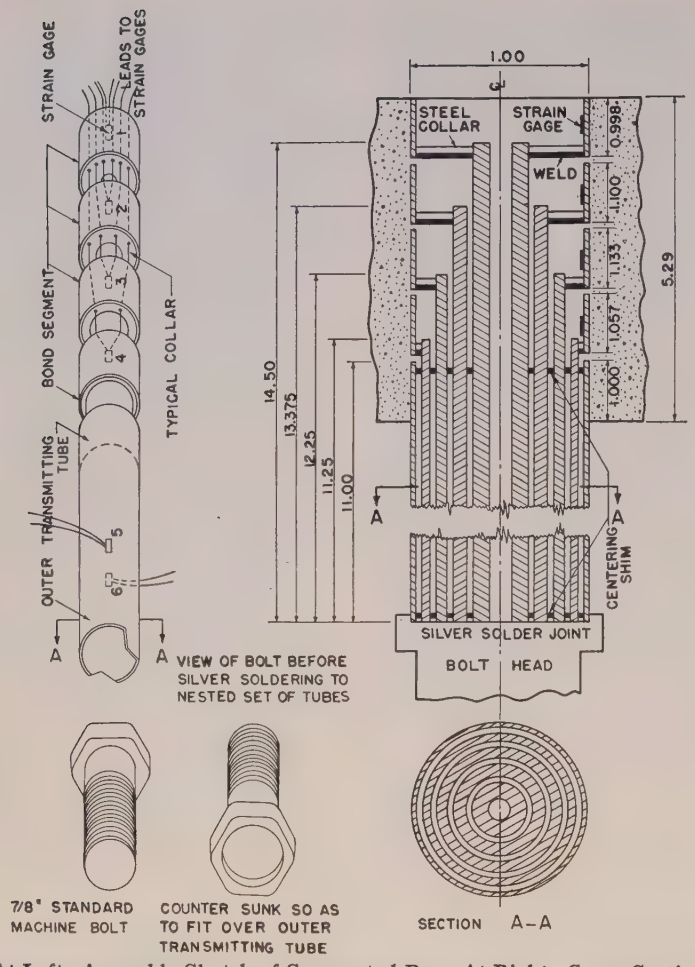

Fig. 1—At Left: Assembly Sketch of Segmented Bar; At Right: Cross-Section of Five-Segmented Bar Specimen.

ments were barely separated from one another by a very thin layer of wax which was pushed into the joints in order to prevent moisture from the concrete from getting inside the specimen and also to prevent the formation of concrete keys between segments.

Figure 1 also shows, by diagrammatic cross-sections, additional details of the arrangement of the transmitting tubes; the bond segments attached to them by $\frac{1}{8}$-in. thick steel disk collars, silver soldered to both tube and segment; the positioning of strain gages; and the method of attachment of the telescoped transmitting tubes to the head of the bolt through which the pull-out force was applied.

Table I gives the pertinent dimensions of the transmitting tubes and bond segments.

Excessive deflection or dishing of the steel collars attaching the bond segments to the transmitting tubes would, of course, cause intolerable errors. The critical collar was obviously the one connecting the innermost tube with the end segment, namely, the collar of maximum diameter. Figure 2 illustrates a special test that was conducted so that the dishing of this collar could be determined and its effect evaluated. The elongations measured by the top, center, and bottom strain gages were designated as A, B, and C respectively. Since the center strain gage straddled the joint and recorded elongations over equal lengths of tubing, the dishing or deflection, y, of the collar was computed by the equation $y = B - \frac{1}{2}(A + C)$. Tests revealed that the error involved at the critical joint was less than 5 per cent.

Electric strain gages were used to compare the test behavior of the specimens with design predictions. One A-7, SR-4 gage of approximately 120 ohms resistance was mounted on the inside at the mid-length of each bond segment. In addition, two (sometimes four) gages were placed around the circumference of the outermost transmitting tube. In order to obtain comparable results, the gages on the bond segments were applied along a common line parallel to the axis of the segmented bar. Two gages were cemented to the outside of the outermost transmitting tube at a distance 5 in. from the bolt head and 18

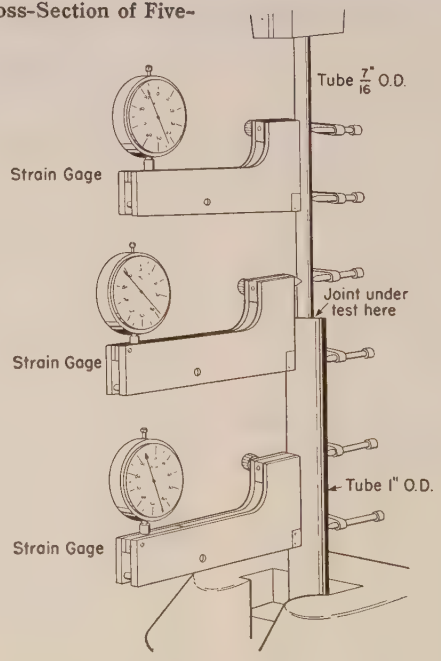

Fig. 2.—Dishing of Collar Test.

TABLE I.—DIMENSIONS OF THE TRANSMITTING TUBES AND BOND SEGMENTS.

Transmitting Tube	Outside Diameter, in.	Gage	Cross-Sectional Area, sq. in.	Length of Transmitting Tubes, in.	Length of Bond Segments, in.
No. 5.....	1	22	0.0855	11	1.0000
No. 4.....	$\frac{7}{8}$	20	0.0924	11.25	1.0567
No. 3.....	$\frac{3}{4}$	18	0.1079	12.25	1.1332
No. 2.....	$\frac{5}{8}$	16	0.1144	13.375	1.1004
No. 1.....	$\frac{7}{16}$	12	0.1125	14.50	0.9982

deg. apart. All internal gages were waterproofed by successive coatings of liquid rubber compound brushed over the gage and then baked.

In order to secure a comparison, "normal" pull-out tests were conducted with unsegmented specimens. These co

ABLE II.—TYPICAL STRAINS IN BOND SEGMENTS OF FIVE-SEGMENT REINFORCING BARS.

Applied Force, lb.	Strains, microinches per inch indicated by				
	Gage 1	Gage 2	Gage 3	Gage 4	Average, Gages 5 and 6
0	0	0	0	Broken	0
100	0	1	−1		10
200	0	0	−2		15
400	2	0	−1		30
520	3	2	2		39
600	3	2	1		42
750	7	5	5		51
920	13	11	7		59
1000	14	11	8		69
1150	17	12	8		78
1250	20	12	9		82
1400	23	18	11		90
1500	24	20	15		98
1600	30	22	16		101
1700	31	27	18		105
1900	40	38	27		116
2050	40	40	29		115
2200	44	51	38		119
2350	51	62	48		112
2460	57	80	70		112
2600	62	99	96		112
2720	63	112	126		111
2800	70	135	150		104
2900	71	171	200		104
2950—Failed at this load			...		...

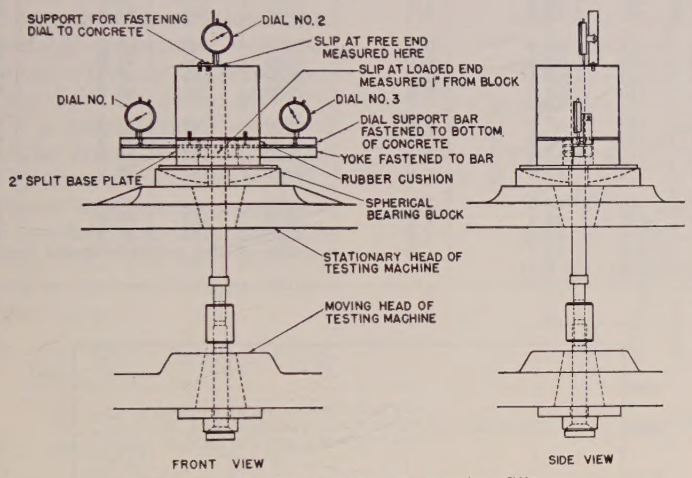
SUPPORT FOR FASTENING DIAL TO CONCRETE
DIAL NO. 2
SLIP AT FREE END MEASURED HERE
SLIP AT LOADED END MEASURED 1" FROM BLOCK
DIAL NO. 1
DIAL NO. 3
DIAL SUPPORT BAR FASTENED TO BOTTOM OF CONCRETE
YOKE FASTENED TO BAR
2" SPLIT BASE PLATE
RUBBER CUSHION
SPHERICAL BEARING BLOCK
STATIONARY HEAD OF TESTING MACHINE
MOVING HEAD OF TESTING MACHINE
FRONT VIEW
SIDE VIEW

Fig. 3.—Testing Rig for Measuring Slip.

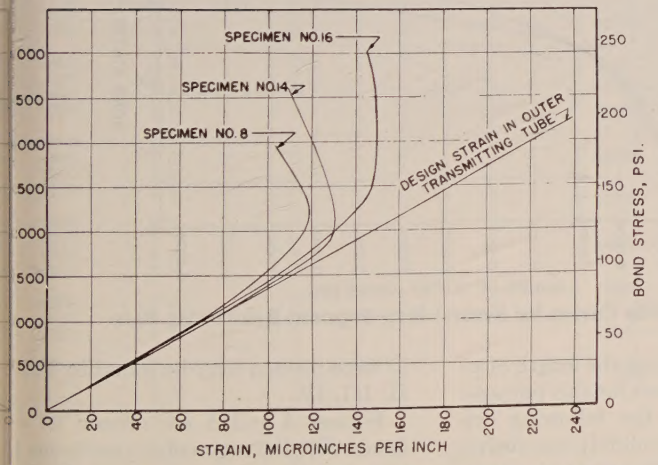

Fig. 4.—Comparison of Strain in Outer Transmitting Tube for Five-Segment Reinforcing Bars.

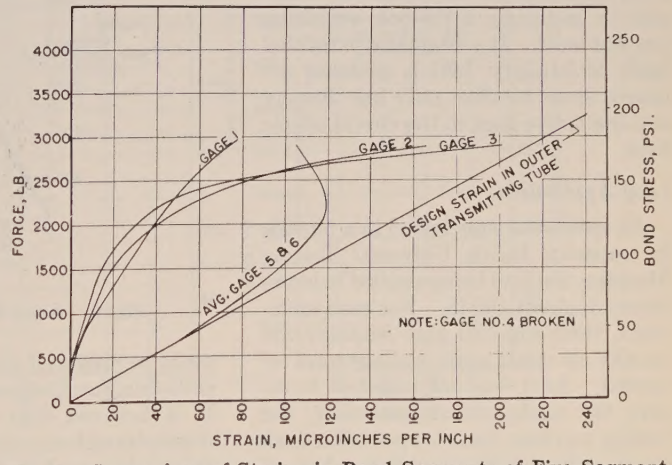

Fig. 5.—Comparison of Strains in Bond Segments of Five-Segment Reinforcing Bar.

ted simply of steel tubes 20 in. long, 1 in diameter, with $\frac{1}{4}$-in. wall thickness. The concrete in which the previously scribed bars were cast was made of al sand and gravel, the latter being of alf-inch pea" variety. The cement met A.S.T.M. specifications for type I cement(C-150).[3] Proportions by weight were 1:2.28:2.94; water-cement ratio 7.03 gal. per sack. Curing was effected by the use of "Clear Cure" sprayed on the concrete a few hours after casting. This was done because storage in a moist room could possibly have damaged the strain gages. However, for comparison, 6 by 12-in. control cylinders were both moist-room cured and "Clear Cured." The former showed a 7- and a 28-day strength of 1890 and 3410 psi.; the latter, 1720 and 2615 psi. All specimens were cast in $\frac{1}{2}$-in. plywood forms so that the concrete blocks were 6 by 6 in. in cross-section and equal to the length of embedment parallel to the pull.

Testing Procedure

Slip Measurements:

Although the primary purpose was to develop and prove a technique for applying a nearly uniform load along the embedded length of a bar, a secondary objective was to correlate this applied force with slip. The authors are indebted to Arthur P. Clark for suggesting the method for making slip measurements; the device employed was patterned exactly after that used by him previously.[4] Figure 3 shows this rig in such detail that descriptive text is hardly necessary. It need only be said that slip at the loaded end of the steel specimen was taken as the average of the readings of the two gages at either end of the bar supporting them. These readings were corrected for the elongation of the specimen in the 1-in. length between the point of attachment of the yoke and the face of the concrete. The slip at the free end was read directly from the gage attached to the top face of the concrete block by bolts screwed into nuts cast in the concrete. All three gages were of the 0.0001-in. dial type.

Strain Measurements:

The strains in the several bond seg-

[3] 1949 Book of A.S.T.M. Standards, Part 3, p. 1.

[4] Arthur P. Clark, "Comparative Bond Efficiency of Deformed Reinforcing Bars," *Journal*, Am. Concrete Inst., Vol. 18, No. 4, Part I, December, 1946; *Proceedings*, Vol. 43, p. 386.

TABLE III.—STRAIN AND SLIP RESULTS FOR FIVE-SEGMENT REINFORCING BARS.

Specimen No. 6			Specimen No. 8		Specimen No. 14				Specimen No. 16			
Applied Force, lb.	Slip, in.		Applied Force, lb.	Strain[a]	Applied Force, lb.	Strain[a]	Slip, in.		Applied Force, lb.	Strain[a]	Slip, in.	
	Loaded End	Free End					Loaded End	Free End			Loaded End	Free End
0..	0	0	0..	0	0..	0	0	0	0..	0	0	0
80..	0.6 × 10⁻⁴	0	100..	10	100..	6	0.2 × 10⁻⁴	0	120..	8	0.2 × 10⁻⁴	0
180..	0.7	0	200..	15	280..	21.5	0.8	0	200..	17	0.1	0
300..	0.9	0	400..	30	400..	32	0.9	0	300..	25	0.5	0
					500..	35.5	1.1	0	460..	36	0.9	0
400..	1.1	0	520..	39								
500..	1.2	0	600..	42	600..	43	1.6	0	600..	45	1.3	0
600..	1.6	0	750..	51	700..	50.5	1.7	0	700..	53	1.7	0
750..	1.8	0	920..	59	800..	60	1.9	0	850..	61	2.1	0
					900..	67	2.3	0	950..	67	2.1	0
900..	2.2	0	1000..	69								
1100..	3.0	0	1150..	78	1000..	75	2.5	0	1050..	76	2.5	0
1270..	3.3	0	1250..	82	1150..	82	2.9	0	1150..	82	2.6	0
1400..	3.7	0	1400..	90	1250..	89	3.1	0	1300..	89	3.1	0
					1350..	97	3.5	0	1450..	101	3.5	0
1650..	4.2	0	1500..	98								
1750..	4.6	0	1600..	101	1500..	105	3.9	0	1550..	107	3.9	0
1950..	5.5	0	1700..	105	1600..	114	4.1	0	1650..	112	4.5	0
2120..	6.0	0	1900..	116	1700..	122	4.5	0	1750..	119	5.1	0
					1800..	126	5.0	0	1800..	123	5.0	0
2280..	6.4	0	2050..	115								
2500..	7.7	0	2200..	119	1900..	130	5.5	0.1 × 10⁻⁴	2050..	133	6.7	0
2700..	9.3	0	2350..	112	2000..	131	6.2	0.1	2200..	141	8.1	0
2950..	11.1	0	2460..	112	2100..	125	9.8	0.1	2350..	144	9.8	0
					2200..	128	10.7	0.2	2500..	147	11.5	0
3100..	12.9	0	2600..	112								
3300..	21.7	0.5 × 10⁻⁴	2720..	111	2300..	129	12.5	0.2	2650..	147	13.8	0
3470..	26.0	0.5	2800..	104	2400..	127	14.2	0.3	2790..	150	16.2	0
3570..	29.5	0.5	2900..	104	2500..	126	16.2	0.3	2900..	148	19.5	0
3700..	33.1	0.5	2950—	Failed at this load	2600..	126	19.0	0.4	3050..	148	21.0	0.1 × 10
					2700..	124	21.0	0.5	3150..	149	22.5	0.2
3800..	33.5	0.5			2800..	125	22.8	0.6	3300..	151	25.0	0.2
3900..	37.3	1.0			2900..	120	25.1	0.7	3400..	149	27.0	0.4
4000..	37.7	1.0			3000..	119	28.6	0.8	3530..	149	30.0	0.6
4100..	41.7	1.0										
					3100..	119	30.6	0.8	3650..	148	31.6	0.8
4200..	45.0	1.5			3200..	115	33.9	0.9	3750..	148	32.5	0.9
4300..	47.5	1.5			3300..	115	36.4	1.0	3850..	147	34.5	1.0
4400—Failed approaching this load					3400..	118	37.0	1.0	3900..	147	36.0	1.1
					3500..	116	40.6	1.1	3980..	144	37.6	1.2
					3600..	113	43.4	1.2	4050..	146	38.8	1.4
					3700..	109	47.4	1.6	4100..	155	40.2	1.8
					3800..	110	51.7	1.8	4200—Failed approaching this load			
					3950—Failed at this load							

[a] Strains in outer transmitting tube in microinches per inch.

ments, as indicated by the SR-4 strain gages, were measured by a portable SR-4, type K strain indicator manufactured by the Baldwin Locomotive Works. Because a number of gages had to be read in rapid succession, and in order to eliminate variations of resistance in switching, a ten-pole switching box was built. It contained a paralleled bank of Mallory 1361-L switches arranged so as to allow only one dummy and one active gage in the circuit at one time.

Load Application:

All specimens were tested in a 50,000-lb. capacity Riehle Universal Testing Machine, the load being applied in increments of about 100 lb. For each increment, three slip dial gage readings and usually six strain gage readings were recorded. As it was not practical to record the readings simultaneously, the testing machine was stopped after each increment and the readings taken as quickly as possible. The time interval between complete sets of readings was between 2 and 3 min.

Results and Discussion

As has been stated previously, one purpose of this research was to demonstrate whether or not a nearly uniformly distributed reaction to a pull-out force could be produced along the length of an embedded bar designed for this purpose. It is believed that the following evidence, though not absolutely conclusive, will indicate that the test specimens acted essentially in accordance with their design.

In order to meet printed space restrictions, it has been possible to include only a fraction of the data. However, a conscientious effort has been made to select examples typical of both consistency and variation. Data from which the curves (appearing in Figs. 4 through 9) were plotted may be found in Tables II, III, IV.

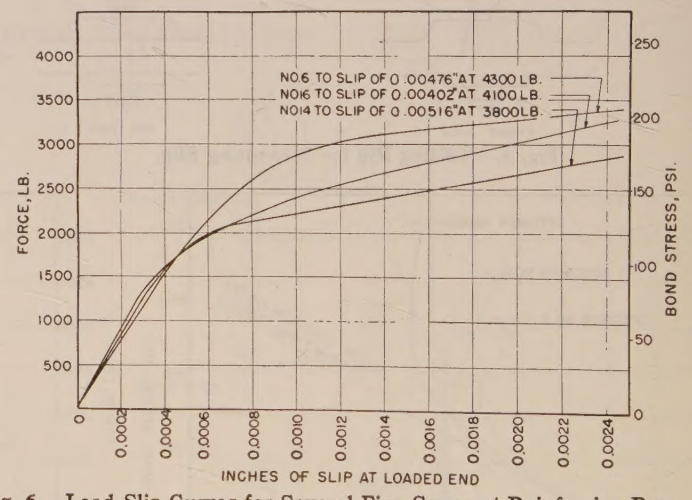

Fig. 6.—Load-Slip Curves for Several Five-Segment Reinforcing Bars.

Figures 4 and 5 are offered as evidence that the segmented specimens behaved as they were intended. In these figures, strain is plotted against load, pull-out force and bond stress. The bond stress ordinate was obtained by dividing the applied load by the embedded surface area of 16.6 sq. in.

In Fig. 4 the strain in the outer transmitting tubes follows the design value closely until the applied load reaches a value of about 1000 lb.;

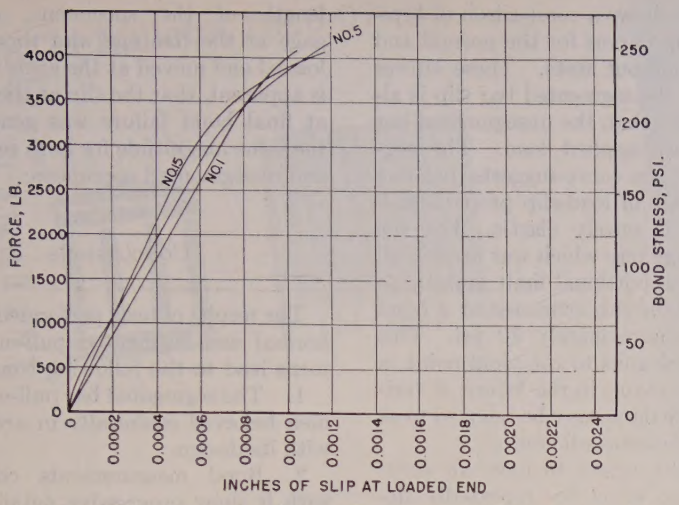

Fig. 7.—Load-Slip Curves for Several Unsegmented Reinforcing Bars.

to say, these tubes were taking their per share of the load at least to the nit indicated.

In Fig. 5 strain in the outermost tube the assembly corresponds well with sign values. But the strains meas-ed in the bond segments, although puped in a definite band, are much aller. The grouping of the strains corded by these gages shows that the nd segments to which the gages were ached, together with the outermost nsmitting tube, were each receiving proximately an equal share of the al applied force.

BLE IV.—SLIP RESULTS FOR TYPICAL RMAL PULL-OUT SPECIMEN (UN-SEGMENTED BAR).

Specimen No. 15.		
Applied Force, lb.	Slip, Free End, in.	Slip, Loaded End, in.
0	0	0
100.....	0.4×10^{-4}	0
200.....	0.4	0
300.....	0.6	0
400.....	0.8	0
500.....	0.7	0
600.....	1.2	0
700.....	1.1	0
800.....	1.3	0
900.....	1.5	0
1000.....	1.9	0
1100.....	2.1	0
1200.....	2.3	0
1350.....	2.7	0
1560.....	2.9	0
1650.....	3.0	0
1800.....	3.2	0
1950.....	3.7	0
2100.....	3.8	0
2300.....	4.2×10^{-4}	0.1×10^{-4}
2500.....	4.6	0.1
2650.....	5.3	0.2
2800.....	5.7	0.3
2950.....	5.8	0.4
3050.....	6.0	0.5
3150.....	6.5	0.5
3250.....	6.7	0.5
3350.....	6.9	0.6
3450.....	7.5	0.7
3550.....	7.7	0.8
3650.....	7.9	0.8
3750.....	8.6	1.0
3800.....	9.1	1.5
3850.....	9.6	1.6
3900.....	9.8	1.7
3950.....	10.3	1.7
4000.....	11.2	2.5
Failure at 4000		

ever, were mounted at the midpoints of 1-in.-long bond segments embedded in concrete. Since each segment was acting in itself as a normal pull-out test, with strain in the segment varying from a maximum at one end to a minimum at the other, these gages were necessarily recording smaller strain for a given pull-out force than were those on the outermost transmitting tube. The fact that these gages were mounted on the inside surfaces of the bond segments whose outer surfaces were receiving load through bond with the concrete, whereas the gages on the outermost transmitting tube were recording a strain uniformly distributed over the tube cross-section, is another factor in the wide discrepancy in their order of magnitude.

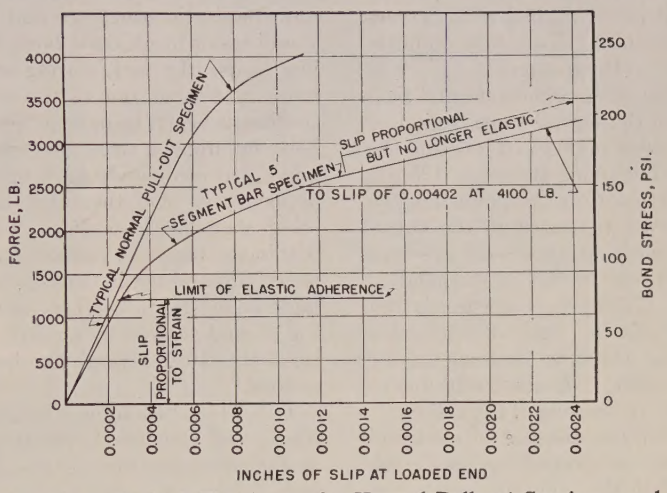
TYPICAL NORMAL PULL-OUT SPECIMEN
TYPICAL 5 SEGMENT BAR SPECIMEN
SLIP PROPORTIONAL BUT NO LONGER ELASTIC
TO SLIP OF 0.00402 AT 4100 LB.
LIMIT OF ELASTIC ADHERENCE
SLIP PROPORTIONAL TO STRAIN
FORCE, LB.
BOND STRESS, PSI.
INCHES OF SLIP AT LOADED END

Fig. 8.—Comparison of Load-Slip Curves for Normal Pull-out Specimen and Five-Segment Bar Specimen.

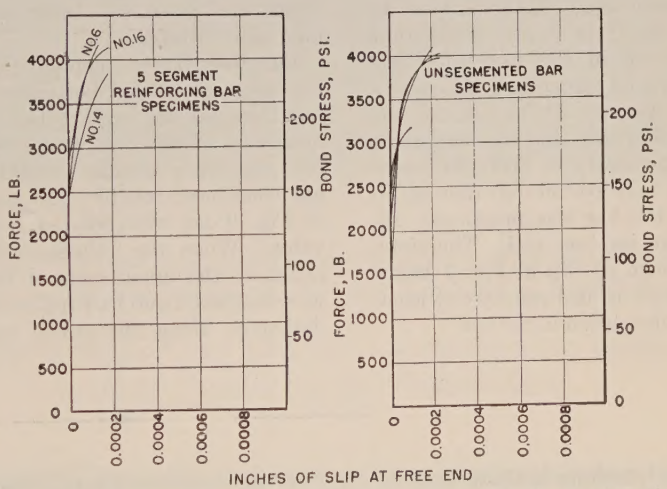

Fig. 9.—Comparison of Load-Slip Curves for Normal and Five-Segment Pull-out Tests.

The question naturally arises as to the inequality of the recorded strains measured above. Part of the answer lies in the positioning of the electric strain gages. Those on the outermost transmitting tube were measuring the strain in this tube before it entered the concrete. The remaining gages, how-

It is regretted that these circumstances were not foreseen. Undoubtedly a more convincing demonstration would have resulted had the strain gages been placed directly on each of the telescoped transmitting tubes, instead of on the bond segments attached to them.

These data verify, by inference, the

principle of the segmented pull-out bar.

The slip curves shown in Fig. 6 indicate some interesting possibilities. One notices immediately that each load-slip curve is made up of three parts which may be described as (1) a straight line for low applied loads, (2) a curved line for intermediate loads, and (3) a straight, relatively flat line for high loads. By comparing these curves with the strain curves in Fig. 4, one notes that (1) the straight portion of the slip curve corresponds generally to the portion of the strain curve that follows the design strain line; (2) the curved portion of the slip curve corresponds to the portion of the strain curve that curves away from the design strain line; and (3) the straight, relatively flat portion of the slip curve corresponds to the portion of the strain curve in which strain values tend to diminish. This may indicate that there are three stages of failure in bond for the type of concrete and bars tested, with the second stage beginning at a bond stress of 60 to 70 psi., and the third stage beginning at around 125 psi.

It is well to note at this point that the greatest strain indicated in the outermost transmitting tube was approximately 250 microinches, corresponding to a stress of 7500 psi. Since this is well within the elastic limit of cold-rolled steel tubing, the large movements for small increments of load must be due to slip and not to yielding of the tubing.

Except for the absence of electrical strain gages, normal pull-out specimens were tested in the same manner as the modified pull-out specimens. Figure 7 shows load-slip curves for three normal pull-out specimens. These curves do not show the three stages of slip that were indicated in the segmented bar tests. Since, by the method of measurement employed, slip at the free end was not observable until load applications in the neighborhood of 3000 lb. were reached, it may be inferred that up to this point the bar was practically anchored near its free end. Therefore, what is shown as slip in Fig. 7 below about 3000 lb. is, in large part at least, the elastic elongation in the bar.

Figure 8 shows a comparison of typical load-slip curves for the normal and modified pull-out tests. These curves show that the segmented bar slip is always greater than the unsegmented bar slip for any applied load. The segmented bar slip curve suggests that in a limited range of load-slip proportionality, bond is purely elastic. For the 2600 psi. concrete which was used in all tests, the proportional limit appears to be reached for this specimen at a bond stress of approximately 70 psi. This point is analogous to the yield point in steel and perhaps, in the future, if verified by more data, may be referred to as the limit of elastic adherence.

One might expect to have an accumulated slip effect by repeatedly developing bond stresses greater than the limit of elastic adherence and that this would result in ultimate bond failure at low loads. In fact, during some preliminary testing, one of the segmented specimens began to indicate progressive bond failure at a stress of about $0.04f'_c$ and failed completely after only twelve applications. On the other hand, another segmented specimen was tested within the region of proportionality between slip and strain, that is, below the limit of elastic adherence indicated in Fig. 8, and showed no signs of accumulated slip after several hundred applications.

The A.C.I. "Building Regulations for Reinforced Concrete" specify a $0.04f'_c$ as the allowable bond stress for plain bars, which, in terms of the concrete used in these tests, is 104 psi. It is noted that this value is considerably above the point of elastic adherence mentioned above.

Figure 9 shows a comparison of the load-slip curves for both normal and modified pull-out tests. The slip was measured at the free end. Slip gage readings below a value of 0.00005 were not considered reliable, and the curves of Fig. 9 are extrapolated below this value. When the values of slip indicated by the upper ends of the curve were reached, bond had apparently been destroyed along the entire embedded length of the specimens, and the gage at the free end and those at the loaded end moved at the same rate. It is apparent, that the slip at the free end at final bond failure was generally of the same magnitude for both segmented and unsegmented specimens.

Conclusions

The results of tests performed on both normal and segmented pull-out specimens lead to the following conclusions:

1. The segmented bar pull-out specimen behaved essentially in accordance with its design.
2. Bond measurements conducted with it show progressive details of the bond phenomenon which cannot be revealed by the normal pull-out specimen.
3. These details make possible an evaluation of the limits of bond resistance not hitherto obtainable.

The authors wish to point out that similar tests may be performed on deformed reinforcing bars by attaching small lengths cut from the bars to transmitting tubes. They would also like to suggest that the method lends itself to the measurement of the adherence of materials other than steel and concrete. The tests described were performed only to prove a technique, and it remains for future investigators to develop its various uses. To prove conclusively that the slip interpretations as advanced in this paper are correct, a detailed statistical analysis of numerous tests should be made.

Acknowledgments:

All concrete was supplied by the Arundel-Brooks Corp., of Baltimore while the proportioning and control were done by their consultants, E. L. Conwell and Co., of Philadelphia. Thanks are due both for their gratuitous cooperation. Thanks are also due Peter A. Frassee and Co., Philadelphia, who supplied tubing without charge.

Virginia Polytechnic Institute Summer Program

During the first of a two-term, summer session professional engineering and graduate program Virginia Polytechnic Institute will feature a series of lectures on "Relaxation Methods."

The "packaged" summer program will extend from June 14 to July 22 and from August 2 to September 9, 1950.

Sir Richard V. Southwell will come from England to present his technique of Relaxation Methods. He has been knighted for his pioneering work in this and other fields. His three books received wide acclaim. Dr. Southwell was formerly a professor of engineering science at Oxford and Rector of the Imperial College of Science of Technology, London, and is currently devoting his entire time to the research in Relaxation Methods and their application to engineering and industrial problems.

The regular summer graduate courses are in applied mechanics; architectural, ceramic, chemical, civil, electrical, and mechanical engineering; chemistry; mathematics; wood construction; and physics. Courses can be taken for audit or credit.

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